THE JOURNAL OF ENGINEERING EDUCATION

Published by the Society for the Promotion of Engineering Education

Published under the Supervision of the Publication Committee.
H. S. Boardman, R. I. Rees, F. L. Bishop, Editor, University of Pittsburgh.
Published at Prince and Lemon Sts., Lancaster, Pa.

Entered as second-class matter at the Post Office at Lancaster, Pa., under the Act of March 3, 1870.

New Series Vol. XXI, No. 10. | JUNE, 1931 | Subscription Price, $3.00 per year. Single Copies, 50 cents.

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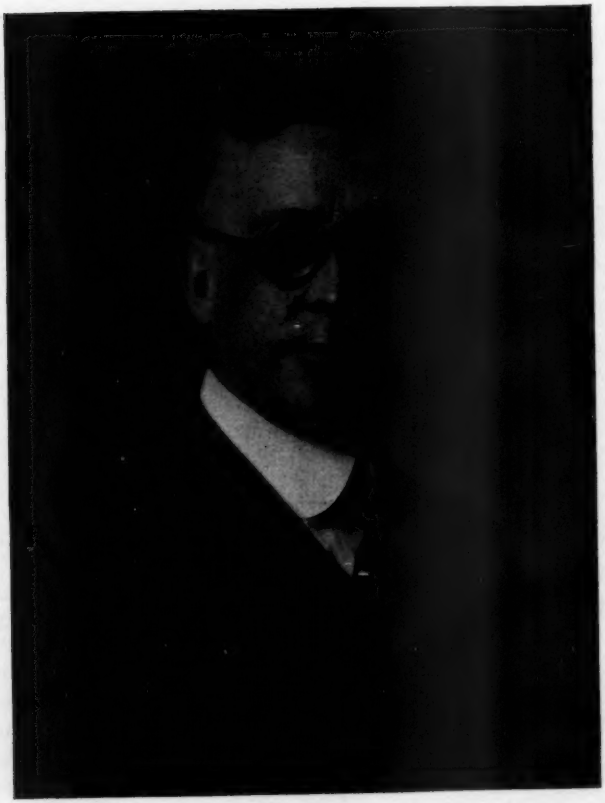


H. S. Boardman.

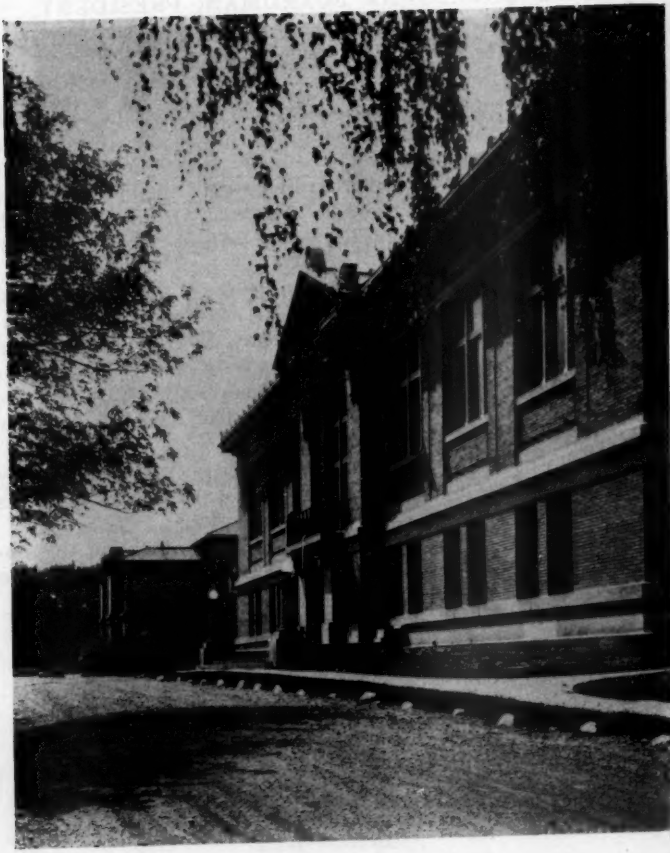
HAROLD SHERBURNE BOARDMAN, PRESIDENT, SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

Harold Sherburne Boardman was born in Bangor, Maine, March 31, 1874. He received the degree of B.C.E. at the Maine State College in 1895; was a graduate student at the Massachusetts Institute of Technology in 1896, receiving his C.E. in 1898. The University of Maine conferred the degree of Dr. Eng., in 1922; LL.D. Colby in 1927; Dr. Eng. Rhode Island State College in 1928; and LL.D. at Bates College in 1929.

President Boardman was tutor in drawing at the University of Maine 1896–99; draftsman and designer at the Union Bridge Company 1899–1900, American Bridge Company, 1900–01; instructor in civil engineering, 1901–03, associate professor 1903–04, professor and head of the civil engineering department 1904–26; dean of the College of Technology, 1910–26 and president since 1925 of the University of Maine.

President Boardman has always been actively engaged in many important hydrographic, structural, hydraulic and highway projects and active in professional and educational societies.

President Boardman was a member of the Council, of this Society in 1919–24, Vice-President in 1923–24, and President in 1930–31.



PURDUE UNIVERSITY LIBRARY

ENGINEERING SCHOOLS AND DEPARTMENTS OF PURDUE UNIVERSITY

By W. A. KNAPP

Professor of Engineering Extension and Secretary, Engineering Experiment Station

Purdue University, the land grant university of Indiana, was founded in 1869. In accordance with an act signed by the Indiana General Assembly, it bears the name of John Purdue, a citizen of Lafayette, who donated a substantial sum of money and land to aid in its establishment. The first classes were conducted from March to June, 1874, several years being required to organize the courses, to construct the three original buildings, and to get the University actually under way. The first full academic year began in September, 1874, with six faculty members and 65 students. The first degree was granted in June, 1875.

Purdue University offers four-year curricula in Engineering (Chemical, Civil, Electrical, Mechanical, and Industrial Education), Agriculture, Home Economics, Physical Education, Pharmacy, and Science. Although all schools have shown a rapid and healthy growth, that of the Schools of Engineering has been the greatest.

The four-year curriculum in the School of Mechanical Engineering was first offered in September, 1882; and one student was graduated from this course in June, 1885. The School of Civil Engineering was started in 1887; the School of Electrical Engineering in 1888; and the School of Chemical Engineering in 1910. The graduating class of 1888 listed five civil engineers and five mechanical engineers out of a total of 30. In June, 1930, 46 men were graduated in chemical engineering, 79 in civil, 111 in electrical, 102 in mechanical, and 3 in industrial education—making a total of 341 engineers out of a class of 547. Degrees conferred at the end of the summer session brought the number of engineering graduates for 1929–30 to 382.

On February 15, 1931, 4,744 undergraduate students were enrolled in Purdue University. The enrollment in engineering was as follows:

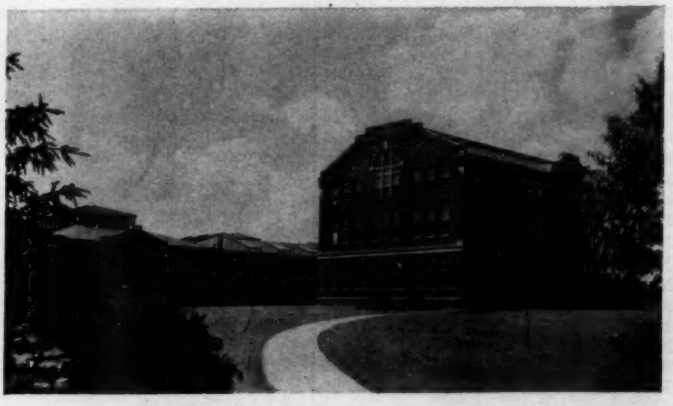
(*a*)	Undergraduates—		
	Chemical Engineering	393	
	Civil Engineering	553	
	Electrical Engineering	781	
	Mechanical Engineering	1,117	
	Industrial Education	25	
	Total		2,869
(*g*)	Graduate Engineering Students		90
	Total		2,959

ELECTRICAL ENGINEERING BUILDING

CIVIL ENGINEERING BUILDING

This represents a total increase of 143 undergraduate students over the enrollment on February 15, 1930.

Three Deans have been at the head of the Schools and Departments of Engineering since the Engineering Division of the University was organized into schools in 1890. Wm. F. M. Goss, the first Dean of Engineering, served from 1890 to 1907, having been on the staff of Purdue University since 1879. Charles H. Benjamin came to the University from Case School of Applied Science in 1907 and served until 1920. Andrey A. Potter, the present Dean of Engineering, came to Purdue in 1920 from Kansas State College where he had served as Dean of Engineering for seven years.



MICHAEL GOLDEN SHOPS

The Schools and Departments of Engineering are organized to carry on three distinct services of value to state and nation. These services are undergraduate and graduate instruction, research, and extension.

Engineering instruction is carried on through four schools, Chemical, Civil, Electrical, and Mechanical Engineering, and two Departments, Applied and Practical Mechanics, with a total teaching staff of 108 people. The engineering curriculum in Industrial Education is also administered under the Dean of Engineering. Since 1885 there have been graduated 6,870 engineers in the regular four-year courses in engineering. Table I shows the enrollment and number of graduates by years in each engineering course since 1908.

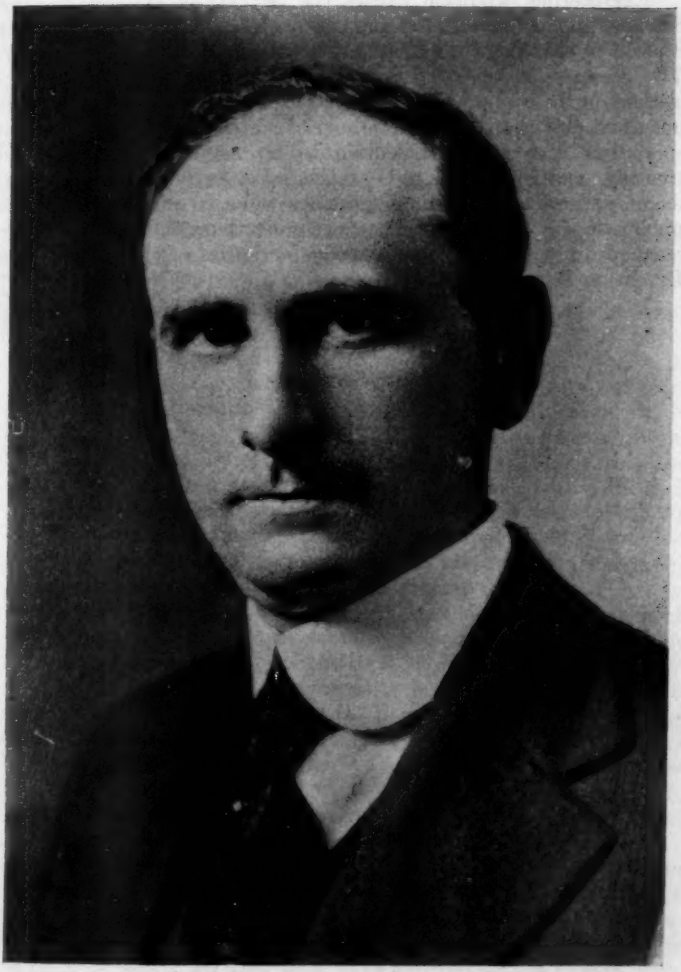
TABLE I

TABLE SHOWING THE ENROLLMENT AND NUMBER OF GRADUATES IN THE ENGINEERING SCHOOLS AND DEPARTMENTS SINCE 1908
(GRADUATE STUDENTS NOT INCLUDED)

Year	Undergraduate Enrollment by Schools						Engineering Graduates					
	Chem.	Civil	Elect.	Mech.	Ind. Edu.	Total	Ch.E.	C.E.	E.E.	M.E.	Ind. Edu.	Total
08–09	51	441	432	373		1,297	1	75	78	86		240
09–10	67	385	408	346		1,206	1	79	72	70		222
10–11	79	346	401	310		1,136	9	79	71	62		221
11–12	74	309	375	342		1,100	10	79	60	50		199
12–13	105	249	351	339		1,044	14	60	69	42		185
13–14	130	232	345	365		1,072	13	36	68	54		171
14–15	138	240	321	348		1,047	13	46	59	58		176
15–16	171	200	312	351		1,034	18	39	52	56		165
16–17	198	210	317	346		1,071	24	42	49	58		173
17–18	189	167	239	254		849	16	23	33	36		108
18–19	270	337	417	638		1,562	19	15	27	50		111
19–20	296	350	463	589		1,698	31	36	37	69		173
20–21	266	397	499	635		1,797	39	56	55	71		221
21–22	232	403	545	638		1,818	45	62	68	106		281
22–23	183	417	520	603		1,723	54	82	90	130		356
23–24	167	412	556	543		1,678	30	63	76	91		260
24–25	172	476	637	535	2	1,822	40	69	85	119	1	314
25–26	171	490	689	569	4	1,923	20	69	89	107	5	290
26–27	207	538	773	548	3	2,069	33	73	76	72	1	255
27–28	229	565	765	676	11	2,246	17	79	82	98	2	278
28–29	254	587	778	817	14	2,450	30	78	121	109	5	343
29–30	300	621	787	980	21	2,709	49	92	125	113	4	383
30–31	393	553	781	1,117	25	2,869						
Total Graduates							526	1,801	2,152	2,373	18	6,870

Engineering research is carried on by the engineering schools and departments through the Engineering Experiment Station, which was organized in 1917. This division has grown from one paid research assistant in 1917 to sixty-five full-time and ten part-time research men in addition to the teaching staff, and graduate and undergraduate students who have been carrying on research during the current year.

Research projects are being carried on in the fields of chemical, civil, electrical, and mechanical engineering, with major attention to railway, concrete, high voltage, and welding problems. Results of completed tests have been published in thirty-four Experiment Station Bulletins. The Engineering Experiment Station spent $285,000 for research during the past year, of which $240,000 was furnished by coöperating agencies.



ANDREY A. POTTER, S.B., D.ENG.,
DEAN OF ENGINEERING, PURDUE UNIVERSITY

Engineering extension carries the benefits of the Engineering Schools and Departments and of the Engineering Experiment Station to citizens of the state not in attendance at the University. The services of this department include conferences and short courses on the campus, coöperation with state organizations in their meetings, extension classes in industrial centers, services of extension specialists with special attention to foremanship training, steel treating, and highways, radio talks, talks to technical and non-technical groups, vocational guidance talks to high schools, and publications. During the past year more than 15,000 people were reached directly through the various activities of the Engineering Extension Department.

LIBERALIZING OBJECTIVES IN ENGINEERING EDUCATION

By DEAN L. E. AKELEY,
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The special urgency of the matter of this paper was suggested by the nature of the reception given last summer at Montreal to Elliott Dunlap Smith's paper on "Management." The writer judges the reception of that paper by the limited interest shown by the attendance at the session devoted to it, by the character of the discussion which followed, and by comments afterwards heard. It seemed as though the matter treated in that paper does not *fit in* especially well with that which has constituted the subject matter of engineering education. The methods for developing a sensitiveness to human relations seemed hardly congenial to men trained in the ways in which the great body of engineers have been educated. It certainly can be no exaggeration to say that Elliott Dunlap Smith's paper on management at the Montreal meeting was not very well assimilated by the membership of the Society. Engineers seem to be lacking in that background that would welcome into the foreground of their interest and professional consciousness such psychological and human considerations as those to which Smith's paper invited the attention of the S. P. E. E.

But the engineering profession is being challenged by new opportunities and new obligations. Engineers are, no doubt, being called upon to project educational ways that transcend the limitations of those in which they themselves were prepared for entrance into the profession. This constitutes a summons to a particularly difficult task. But no difficulties can justify neglect of the terms of a new call to meet a new time.

There has been more or less demand on the part of certain engineering deans and professors for the introduction of a larger number of so-called cultural subjects into engineering curricula. These demands have not met with any very marked success. It is the belief of the writer that they have enjoyed all the success they deserve. It is not a promising educational proposition to impair the excellence of the engineers present training by introducing the materials of a culture that has become exotic to the civilization which is now in process of evolution. We may have in time an academic culture that will be more fully indigenous to the broader popular culture of the modern world. If the present subject

matter of the engineering curricula be presented and developed in the student's conception and mastery of it, in a way to sensitize his mind to the kind of problems that the contemporary world is facing, there will be plenty of cultural appeal in it all. The very course that calls upon the student for cultural interest will all the more effectively focus his energies upon his narrower vocational objectives.

There are many other considerations besides those suggested by the reception of Smith's paper which should give us a bad conscience about a certain ineffectiveness in current engineering educational objectives. In the December *Harper's* was an article by Harold J. Laski on the "Limitations of the Expert." That paper presents matters that deserve consideration, together with interpretations and conclusions that may be open to some criticism. In concluding his paper Laski says, "We must ceaselessly remember that no body of experts is wise enough, or good enough, to be charged with the destiny of mankind. Just because they are experts, the whole of life is for them in constant danger of being sacrificed to a part, and they are saved from disaster only by the need of deference to the plain man's common sense. . . . The experience of the expert is so different, his approach to life so dissimilar, that expert and plain man are often impatient of each other's values. Until we can somehow harmonize these, our feet will be near to the abyss."

Perhaps, there is no body of experts less deserving of Laski's criticisms than are the professional engineers. But even they deserve these criticisms in notable measure. Laski holds that experts in government and in economics require the politician to draw the line beyond which their very prestige as experts disqualify them for consideration. And in general he claims that the expert must have deference for the plain man's common sense. Why would it not be good for society if the expert could, along with all that acquired knowledge and all those abilities which make him expert, preserve his native common sense, cultivated and developed under a sensitiveness, awakened by his education, to the human and cultural facts which condition the situations which call for his expertness. Is any plain man or are all the plain men together, who happen to rise to political, financial, or industrial eminence, good enough or wise enough to be intrusted with the destiny of mankind? If we are going to escape the abyss by harmonizing the values of the plain man and those of the expert had we not better concern ourselves with those features of the expert's education during his plastic age which so narrow his outlook as to make him dependent upon plain men whose rise to eminence comes about from a great variety of causes. The engineering expert's training has a scientific basis. It is certainly important to mobilize all the scientific resources of the world, including those which are found in the pro-

fessional engineers, for the solution of the challenging and threatening problems that confront modern industry and economic organization.

The contemporary troubles of civilization, constitute, on an exceptionally large scale, the same kind of problem that has been solved in the past by individual genius in scientific discovery. To carry such magnified projects of research, through the coöperation of competent leaders with many diversified interests and of understanding and intelligent followers, is a new challenge. It would look like sheer folly for plain men to dominate the situation, indispensable as their coöperation undoubtedly is. To carry out such projects even by a process of more or less successful muddling through, requires a breadth of understanding on the part of applied scientists, pure scientists, and practical men such as the education of the past has never begun to conceive. It demands an understanding of scientific method on the part of large numbers of persons and a conscious application of it. More than all else, it calls for an appreciation on the part of the rank and file of scientific men, for rare and exceptional kinds of ability which are indispensable in certain stages in the processes of discovery and application. The call is for each one to find his place and keep his place in the great project. To this end much dependence must be placed on the intelligence and knowledge of the individual himself. The great thing that a liberalized education should do is to render the average educated person appreciative of the rôle of—whatever you may call it,—intuition, genius, uncommon common sense, and to render him appreciative of the limitations of the great majority of persons who lack these qualities, even though they have shown themselves susceptible of the most elaborate education. This is a commentary on the present degeneration into scholasticism of most academic research. When students should be getting a grasp of scientific method in all its ways, they are forced into intensive effort in the most limited aspects of it. This intensive effort in limited directions shuts out the possibility of the student's making a fair assessment of his own individual type of ability and of gaining an appreciation of abilities that are out of his range. I know all the objections that will be immediately raised against this statement. But the present pessimism among research men in physics can be traced to this sort of blindness. Many men when properly trained have the ability to apply rigorous deductive methods to the insights of intuitive scientists like Dirac and yet all their progress in clearing up desperate situations that have developed in contemporary physics must wait patiently upon the intuition of the Diracs and the Einsteins. Lesser men may verify these intuitions. The verifications and deductions are laborious and indispensable. But this is a work of

utter futility without the epoch making work of genius. Genius can never be fathomed, but the conditions under which it works and succeeds can be studied and that kind of study will yield an appreciation of the limitations of men of the merely deductive and analytic type, that is most comforting and reassuring, and salutary.

Right here in this connection it must be observed that the rôle of inductive scientific method is not recognized in current educational procedures as it must be if the objectives here pointed out are to receive adequate consideration. Induction is a jump. It is never a jump in *total* darkness. The jump must follow a preparation, consisting of the most strenuous efforts to clear up a perplexed situation. This preparation is followed by what Graham Wallas calls "Incubation," ending in what he calls "Intimation" and "Illumination." The inductive jump completed, has to be followed by the rigorous deductive procedures and verification. But great generalizations and fertile applications of general principles to concrete problems are reached by something that can be called nothing less than a jump, which only a certain type of mind can make with any assurance of success. Yet the mind that cannot do this needs to appreciate his own limitations in this regard and needs to recognize his dependence upon a genius that he can never claim for himself. The present exclusive emphasis on deductive processes as distinguished from the inductive is a serious defect in current scientific education. The defect is not even remedied, except in a very partial way, even in post-graduate work, which, however, lies outside the range of most engineering education.

What is needed above all else in all education today is a cultivation of a sense for those qualities of mind which have given the modern world its science and its applications to the uses of life. Such an education will be liberalizing and will give a culture that is not an exotic. To the end of shaping such liberalizing objectives, the first requisite is an adequate philosophy for our education. Such a philosophy must embrace scientific method completely in all its stages and phases. A philosophy adequate to educational procedures in the interests of an indigenous culture, would be, beyond all question, a pragmatic and realistic philosophy. The whole matter lies quite aside from the questions that are currently discussed by technical philosophers.

Pragmatic philosophy means, in the sense of what the educational situation demands, one that will emphasize in scientific method the common sense or intuitive approach to problematic situations.

It will be claimed that a pragmatic philosophy taken in this sense will demand educational procedures for the freshman and sophomore years, that will take care of interests that are one and

the same for a future researcher in pure and applied science and for the engineering practitioner and for the leader and the follower alike in those economic and political crises for which every good citizen should be trained and prepared.

It would be disastrous to confuse the educational objectives for the future research man and for the engineer. Engineering and research are quite distinct when it comes to the more distinctively engineering courses of the junior and senior years. But it is equally a disastrous idea not to recognize that the fundamentally pragmatic approach to problematic situations is the same for engineers and for researchers. Both are special cases of the use of one and the same scientific method, which it must be the chief task for all who are engaged in any kind of education to understand, so far as that method has emerged from the intuitive processes of the great discoverers of science into the light of clear and intelligible statement. The ways of scientific induction as distinguished from deduction will never be capable of clear statement in a minutely detailed way. But the *conditions* under which great inductive insights are achieved can be clearly and distinctly outlined and introduced as subject matter in every scientific course. It is just this feature that will put a new element into the subject matter of scientific courses. Such matter will impress all students with the fact that there is an inductive process in science and that it is to be treated with respect. Respect for it means that those who have very limited abilities for the achievement of inductive insights must confine their intellectual activities to the critical deductive treatment and experimental verification of the work of men of genius and must patiently wait upon the work of such men for the cues to their own activities. The days of the prophets will return, and of reverence for the prophets to an age when reverence is more or less submerged.

The main question then is the character of the pragmatic approach to a problematic situation. No words are more misleading in many of their implications than the words "applied science." They seem to imply to many persons that science is something already finished, ready for application, *i.e.*, ready to be externally applied to a troubled situation like dope to a sore thumb. The truth of the whole matter seems rather to be that our science, our whole conceptual paraphernalia is not all ready prepared for application to the problematic situation that confronts either engineer or pure scientist. The researcher often finds that his scientific body of principles, laws, concepts, universals, and complexes of universals, must be redefined and reorganized before they can be used to interpret a new experimental situation. The engineer seldom experiences any such revolutionary upset as this in the use of

fundamental principles of science. But he does always experience something every bit as drastic in character in organizing the particular pattern of laws, principles, and concepts for his particular problem and he experiences what is equivalent to a veritable revolution in reorganizing his stereotyped understanding of principles. That is, the engineer experiences all this in greater or less degree as he attacks problems of greater or less difficulty. The generalizations of science never possess for us that generality that we imaginatively impute to them. They are always stereotyped to the particular situations in which we have formerly used them. If they were not so stereotyped we never could apply them to any concrete case at all. They would not possess those concrete earmarks that relate them in our minds to the sensible features of our concrete situation. We never see entropy and heat energy roosting around a diesel engine. We may imagine that we sense temperature in it. But even that is a stereotype and not a concept. Principles and laws are abstractions; so are all our physical concepts. There is a superstition among physicists that these are not abstractions. This superstition arises from the failure to realize that we always limit the generality of them by stereotyping them to the particular situations in which we have used them. Being stereotyped to former situations they are not applicable to the present situation until they have been pretty drastically smashed up in their stereotyped character. On this account anyone who is trying to apply principles to a new situation is between the "devil and the deep blue sea." His principles would not be applicable to any situation if they were not thoroughly stereotyped and since they are stereotyped they are inapplicable to the new situation. This is a dilemma that no logic can solve. Life only can solve it. And life in this case means achievement of an insight by genius. And since many men do succeed in applying principles to new situations, genius must be much more common than is generally assumed. Genius is probably an exceptionally high development of a variant of common sense. In applying principles to new problems, the laws, the principles, the universals, the complex patterns of universals must be rediscovered *in* the new problem, not applied *to* it from without. To do this successfully demands genius of the same nature though not of the same intensity as was exhibited in the original discovery of scientific generalizations. This is the chief lesson that the engineering graduate has to learn during the first few years out of college in the process of vindicating the proposition that he is not an educated fool. We are all educated fools to the extent that we do not recognize that every particular situation has to be approached from the standpoint of common sense. We must let the new perplexity talk to us in its own language and we must forcibly repress our

knowledge, which has cost us so much and which we love to use. We must force that knowledge and the pride that goes with it into the remotest background of our consciousness or even sub-consciousness. Nothing less drastic will ensure that just that part of our knowledge that is relevant will trickle through. The spirit of Elliott Dunlap Smith's address and the spirit of his book, "Psychology for Executives," is just the spirit of the common sensed and pragmatic approach to problems. The book reads in a way to give one the impression that he had learned his psychology in the everyday troubles of an industrial executive. However, a little reflection will persuade anyone that Smith must have in some way acquired a good knowledge of psychology in advance of managerial troubles. But it is equally obvious that he *relearned* all his psychology in dealing with industrial troubles. And he clearly indicated at Montreal the agony through which intuition will carry anybody in relearning what he thinks he knows. The process as he outlined it was something like this. He met the troubles each day as they rose and met them as his practical sense applied to an analysis of the whole situation suggested. He often failed. He faced the same dilemma described above that is always involved in the application of principles to a new problem. Life has to solve a dilemma that logic cannot touch. It is a re-enactment of the drama of Jacob wrestling all night with the angel. Defeat and humiliation is the apparent termination of the whole event. But only apparent, for the Jacobs. For Jacob held the angel, refusing to let go until he had received a blessing. In the case of the industrial manager the blessing is an insight into human situations and the rediscovery, in the kind of problem that has been inflicting defeat, the principles of psychology and the scientifically formulated laws of human nature.

Smith asked the question at Montreal, "Can the Universities Teach Management?" His answer was, No. But they can make students sensitive to human relations and speculative about them. The same question can be asked about everything that universities try to teach. And the answer must be the same as Smith gave, an emphatic No. We cannot teach anything of any great importance aside from a few indispensable techniques. The greatest thing we can do is to make students sensitive to and speculative about the great realities of scientific method, so that when they enter practical life there may be some hope that some of them will rediscover the principles of science in their work. Probably the one feature of Smith's ideas that repelled interest is the one outstanding criticism today for engineering and all other kinds of education.

This then may be the gist of the pragmatic philosophy of education. William James said there were two factors in both life and philosophy, the Thick and the Thin. They master life who

dwell in the thick of life and find *in* life that which transcendentalists place outside of life, that thin conceptual structure that we call science. It is thin and abstract; but, found in perplexed situations, it appears as order coming out of chaos, giving life its beauty and its meanings, its forms and comeliness. The science taught in the textbooks is an abstract from these meanings of life, put into cold storage during the passage from the concrete problems of the past to those of the future.

To pose the problem presented in this paper is more important than a detailed discussion of one of its rather successful solutions in the teaching of one science, viz., physics. There will be other solutions better than the one already fairly well achieved, if the problem in its vast significance is once grasped. The solution of it will conflict with current standardizations. However the solution already well toward completion meets all current standards. The advantage is that it does more. The *more* is the significent thing. It is the *more* that, in addition to its own intrinsic value, makes more effective and more compellingly interesting the achievement of the less, *i.e.*, the meeting of current standards. Standardization would choke off this more. We merely need to heed the words of the Principal of McGill in his address last summer when he said as nearly as I can remember it, "We need to forget standardization and concentrate on standards."

THE CALCULUS IN ENGINEERING SCHOOLS

By EVAN THOMAS,

Professor of Mechanics and Mathematics, Emeritus, University of Vermont.

I

The calculus is a required study in all engineering schools of collegiate grade. Generous provisions are made for it in the curriculum. In an increasing number of institutions these provisions are extended to cover advanced courses in the subject. All this is as it should be. The calculus is the engineer's distinctive arithmetic, very much as trigonometry is that of the surveyor or commercial arithmetic of the banker. The engineer has much to do with related variables, whose variations follow a definable law and it is with problems of this sort that the calculus is concerned. Thus to the engineer the calculus has an utilitarian as well as a cultural interest, and in a sense the former is dominant. Even in cases where the calculus is not immediately useful, a good understanding of the physical principles underlying engineering problems is scarcely possible without some acquaintance with it. The engineer also must know something about differentials if he is to have access to the more advanced professional literature. It is not too much to say that familiarity with the elements of the calculus should form a part of the intellectual equipment of the educated engineer in the same way that some idea of the Copernican astronomy and the theory of evolution should form a part of the intellectual heritage of every educated man.

II

But notwithstanding the acknowledged importance and intrinsic interest of the subject, both from a cultural and practical point of view, the calculus has always suffered from certain blighting traditions which have dampened the ardor and retarded the progress of the student. At a meeting of the S. P. E. E. twenty years ago, the teaching of the calculus to engineers formed the main topic of discussion. It seemed to be the concensus of opinion that the results of the work in this field are lamentably unsatisfactory, and there were experienced teachers present who maintained that not over ten per cent of those who had completed a course in calculus could make any appreciable use of what they had learned.

1. One tradition is that the calculus is essentially mysterious, alien to ordinary modes of thought and of such uncommon difficulty as to be accessible only to exceptionally gifted, not to say peculiarly constructed, minds, who alone can hope to acquire a command of it at all comparable to what they have of arithmetic or trigonometry. Even to good students there is about the subject a certain elusiveness with which it seems impossible to cope. After a year of conscientious effort the student is left with the uncomfortable feeling that all he has to show for his labors is a certain smattering of knowledge of little or no practical use. In the language of Sir George Airy, an experienced teacher of well prepared students: "The results of the differential calculus are received by many rather with the doubts of imperfect faith than with the confidence of rational conviction."

A similar view was expressed by the famous Augustus De Morgan, who wrote in his classical treatise: "It is a matter of common observation that one who commences this study, even with the best elementary works, finds himself in the dark as to the meaning of the processes which he learns, until at a certain stage in his progress, depending upon his capacity, some accidental combination of his own ideas throws light upon the subject. The reason of this may be that it is usual to introduce him at the same time to new principles, processes and symbols, thus preventing his attention from being exclusively directed to one new thing at a time."

The great Cambridge coach and eminent mathematical writer, Isaac Todhunter, in his well known textbook on calculus, says: "It frequently happens that a person commencing this subject is discouraged at the outset because he cannot discover or imagine any practical application of the somewhat abstruse points to which his attention has been directed."

2. Another tradition is that the calculus lacks those qualities of definiteness, precision and manifest logical consistency which are supposed to constitute the distinctive merits of mathematics. A further quotation from Todhunter will express very accurately the experience of many students of the calculus. "A difficulty of a more serious kind appears to embarrass many students of this subject, namely, a suspicion that the methods employed are only approximation, and therefore a doubt as to whether the results are absolutely true. This objection is certainly very natural, but at the same time by no means easy to meet, on account of the inability of the reader to point out any definite place at which his uncertainty commences."

This difficulty was keenly felt by such students as General Nathaniel Lyon, West Point '41, who gives vent to his disgust in this vigorous language: "The inventors of the differential and integral calculus have claimed that this branch of so-called science

belongs to the department of mathematics, and, laboring under the delusion have introduced it into the course of academical instruction for the torture of students. Such classification is obviously incorrect, because the principles of mathematics fall within the scope of the reasoning faculty. The calculus, on the contrary, lies without the boundaries of reason." An examination of the textbooks used in those days would go far to explain, if not to justify, this harsh judgment.

3. A third tradition is that the calculus has very limited professional utility. This contention is not without plausible support. In much of the work in design, the numerous excellent handbooks, rich in tabulated material, dispense to a great extent with the necessity for the direct use of the calculus by reducing the calculations to purely arithmetical operations. It is also true that men of the highest standing in the profession have had but little or no knowledge of higher mathematics and apparently have never been sensible of any loss in consequence. Trautwine in the preface to his famous handbook gives a list of helpful books on engineering, and then adds: "The writer does not include Rankine, Moseley, and Weisbach, because, although the books are products of master minds, and exhibit a profundity of knowledge beyond the reach of ordinary men, yet the language is also so profound that very few engineers can read them. The writer himself, having long since forgotten the little higher mathematics he once knew, cannot. To him they are but little more than striking instances of how completely the most simple facts may be buried out of sight under heaps of mathematical rubbish." This disdain of higher mathematics, so frankly expressed, is due in large part probably to the fact that the writer's acquaintance with the subject was at no time sufficiently thorough to admit of extended practical uses. Besides, the passage is sixty years old. During the intervening period the applications of advanced mathematics to engineering problems have been constantly gaining in number and importance.

III

These traditions are largely if not wholly rooted in a badly chosen starting point. In the textbooks the beginner is led at the outset into regions abounding in notions both novel and nebulous, in enigmas and obscurities, in symbols whose meaning is as hidden as the meaning of the words in Jabberwocker, and in operations contrasting sharply with his previous ideas of mathematical clarity, precision and rigor. He encounters quantities which behave in a most curious and unfamiliar way—functions which approach zero as a limit, fractions with vanishing numerators and denominators but

finite, may be large, quotients, magnitudes so small that Bishop Berkley christened them "ghosts of departed quantities," and orders of magnitude such that a magnitude of a lower order added to one of the next higher order leaves the value of the latter unaltered. Probably Dean Swift had these orders in mind when he penned the familiar gibe:

> "So, naturalists observe, a flea
> Has smaller fleas that on him prey;
> And these have smaller still to bite 'em
> And so, ad infinitum."

The difficulties of the customary modes of approach have been fully admitted by recent writers of textbooks on calculus and strenuous efforts have been made to minimize these difficulties and to render the path of the beginner smoother and more attractive, as may be seen by comparing Todhunter's famous work of sixty years ago with the more recent "Calculus for Engineers" of John Perry. American, English and German writers now follow Perry in the majority of cases, especially when preparing books for engineering schools. These efforts, however, are at best only meliorative and do not reach the real root of the difficulty. The student is still required to traverse a decidedly foggy stretch in passing from the quotient of increments to a quotient of differentials.

The difficulties felt by the beginner could be avoided in part, if not altogether, by a reversal of the customary order of presentation in the textbooks, and the adoption of a more arithmetical approach. Instead of starting with a study of the steps leading to the definition of the differential coefficient and the formulation of the rules for differentiation, a beginning could be advantageously made with an exposition of the differential coefficient and the formulated rules as distinct entities without regard, for the present, to modes of derivation. They are things to be explained and applied and not things to be derived and proved. The derivation and proofs have been provided long ago, and they are things which, provisionally at least, can be advantageously taken on trust. For the present our concern is to understand what they are and not how they have become what they are.

The more suitable form of the differential coefficient for a first approach is that of a fraction whose numerator and denominator are ordinary numbers, representing definite, measurable magnitudes. The distinctive character of this fraction as representing the instantaneous rate of change of one variable with respect to another can now be explained to a beginner in a way he can understand and appreciate. The rules for differentiation, based upon this conception of the differential coefficient, admit of easy explanation. This exposition should be accompanied with and followed by ex-

tended practice in the solution of illustrative problems of a practical sort, of which engineering provides a generous assortment.

IV

Several pertinent considerations in favor of this change of order readily suggest themselves.

1. This is the most intelligible and attractive phase of the subject. The student begins his work with a feeling that he is dealing with substantial realities and not elusive phantoms, which have grown out of attempts to explain and which contribute little directly to practical necessities. What is hazy in conception and obscure in theory is avoided. The abruptness of the transition from his previous studies is minimized. He is now performing operations whose meaning is intelligible and utility obvious. The real significance of the calculus and its practical value are impressed upon the mind at an early stage. The student gets almost at the start a foretaste of the rôle which the calculus plays in engineering. This reversal helps to ward off that vague and uncomfortable sense of unreality which often haunts the mind of the novice and creates a prejudice, not to say a certain repugnance, against the subject.

2. This order provides a favorable starting point for a study of the expedients and logical refinements employed in the derivation of the differential coefficient from the integral equation. It has been said that if we want to show the evolution of the herring from some simpler form, the best way is to begin with a study of the existing form and present habits. If we want to become familiar with the mechanics of the automobile, it is well to begin with a study of the mechanism and it would be no disadvantage to be able to drive. In like manner a sufficient knowledge of the rules of calculus to enable the student to apply them successfully to the solution of obviously worth while problems puts him in a good mood to attack more recondite phases of the subject, and especially does it relieve him of that enfeebling conviction that he has "no idea as to what it is all about." Furthermore, as a machinist picks up a good many useful mechanical ideas and scientific principles while working at his machine, so will a student of calculus catch valuable glimpses of underlying principles while making practical uses of the rules.

3. This inversion is accepted in other subjects, both as a rational expedient and a practical necessity. Students are taught the meaning and uses of logarithms and trigonometric functions long in advance of instruction in the underlying theory and the construction of tables. In the words of the late Professor John Perry: "It is pedantic to say that a man must not use a formula unless he is able to prove its truth. It is usually a great help in learning to prove a

formula to have previously used the formula and know the meaning and value of what we are to prove. A living Northern professor of great eminence has declared that a boy ought not to be allowed to use logarithms until he is able to calculate them; he has not said that a boy ought not to use a watch or to wear a coat until he is able to make them." The rules can be rationally adopted and confidently used because they form a substantial part of a great body of verified knowledge. A traveler who refuses to pass over a bridge the soundness of which he had not tested would not go very far. A boy who would not ride a bicycle or pitch a curved ball until he had mastered the dynamical principles involved would be in the class with the carpenter who would not use the Pythagorean proposition until he found his way back to the axioms. It is wise to take some things on trust even in mathematics.

4. This is the historic order. The rules of the calculus did not have their source in rigorous logic. In fact, they were used correctly and profitably for two hundred years before a sound logical foundation was provided. The formulators of the rules of the calculus were men of sagacious minds and close students of the changing phenomena of the visible world. Intuition and patient reflection upon variable quantity, physical and geometrical, played a far more decisive part in the formulation of the rules than rigorous logic. Confidence in the validity of the rules had its source in the undeniable correctness of the results which followed their application. The greatest masters have been those who make free use of guesses, hunches, divination and other non-logical processes. A correct instinct was at work in the mind of the gentleman in "The Autocrat at the Breakfast Table" when he remarked sagely that most mathematical demonstrations constitute "a pons asinorum over chasms which shrewd people can bestride without such a structure."

Even Newton himself had only very indistinct ideas in this connection. Or if he did he failed to transmit them to posterity. Among his successors one of the most eminent was Colin McLaurin, of McLaurin's formula fame. Yet of him Woodhouse wrote: "Of the commentators on the method of fluxions (the present calculus) McLaurin must be accounted one of the most acute and judicious, but in his Introduction he exhibits rather the exertions of a great genius struggling with difficulties than a clear and distinct account of the subject he was discussing." Until the days of Weierstrass and his school, who, about the middle of the last century, did much to straighten out the logic, the demonstrations of the rules of the calculus were, like the Englishman's metaphysics, "bad reasons for what we believe on instinct." Up to that time mathematicians were so occupied with the applications of the calculus that they treated the rules very much as an eminent English mathematician

treated those for imaginaries. "Whether I have found a logic by the rules of which operations with imaginary quantities are conducted is not now in question; but surely this is evident, that since they lead to right conclusions, they must have a logic."

5. In spite of the labors of Cauchy, Weierstrass and others of lesser note to put the calculus on a satisfactory logical basis, there are not wanting stout unbelievers who contend that a rigorous demonstration of the rules of the calculus is an inherent impossibility. So high an authority in the field of scientific engineering as Sir Oliver Heaviside commits himself to the opinion that for the past "twenty-five years we have erred in attempting to lead the student to a working knowledge of the calculus by first convincing him that the reasoning is sound. It is quite possible that the fundamental principle does not admit of deductive demonstration." As Comte advanced in life he seemed to become increasingly convinced that there is in the calculus a transcendental element which renders all attempted demonstrations alike irrational and futile. The laws of the calculus, like Newton's laws of motion, are to be accepted because in all their applications they are always found to agree with the facts of experience.

V

The primary interest of this paper is pedagogical rather than logical. That is, the chief concern here is not with a logical development of the calculus, but rather with the course likely to prove the most advantageous to the student to whom it is to serve as a tool in his professional work. It is the suggestion of the paper that the desired object can be most effectively achieved by following the principle of learning by doing. There is no intention of encouraging the substitution of shop methods for a thorough basal examination of the subject. In order to have a complete understanding of the calculus and in order to secure a mastery of its uses on the higher levels, the subject should be examined from the point of view of infinitesimals, limiting ratios, first derived functions, as well as those devices by which it is sought to avoid these more recondite aspects.

There is no suggestion in these paragraphs of a calculus made easy. There is no such calculus beyond the title page. The late Professor S. P. Thompson exercised to the utmost his superb genius for exposition in the preparation of the charming little book, "Calculus Made Easy." One does not turn many pages, however, before finding himself face to face with the same old difficulties which have been familiar to students from the days of Newton to the present time. If one will take stock of the mental activities required in the study of the calculus, he will readily satisfy himself that the

subject has no place in the list of easy courses. What is here suggested is that it can be made easier and more attractive to the ordinary student than it now is by concentrating attention and effort at first upon an interpretive study of the rules and practice in their varied applications to the solution of engineering problems. This working knowledge provides, as stated before, a good starting point from which to proceed to the study of the theoretical basis of the rules. In itself, however, even if inaptitude or disinclination should make it inadvisable to struggle with the more subtle phases of the subject, this practical acquaintance with the calculus is a valuable addition to the engineer's intellectual and professional equipment. And in cases of this sort it seems like an open question whether, from educational and cultural standpoints, a thorough command of a few working concepts and rules, reproducible at a moment's notice, are not preferable to a mass of ill-formed ideas admitting of no practical uses and not likely to outlive the embryonic stage.

VI

The teaching of calculus in American colleges falls into three fairly well-defined periods. The first covers roughly the first three quarters of the 19th century. During that period we were plain imitators and translators, depending largely for our ideas upon British and French sources. The texts abounded in misty notions, faulty logic and barren abstractions. There was an utter absence of any concrete material to assist the student in forming any sort of an idea of what the subject was about; nothing to suggest any connection with physical or technical problems, although during all that period the calculus was applied with great success to astronomy, mechanics and engineering. The student was left to struggle with symbols and with operations, of the connection of which with sensible objects he had no conception whatever. It was a required study and enjoyed a great reputation as a source of mental discipline, as well as of perplexity and uncertainty. Among the texts used during a good share of this period were those of Davies and of Church, which are largely forgotten now.

The imitation stage was followed by what may be called the rigorous stage, in which the chief emphasis was laid on the rigorous demonstration of the fundamental proposition of the calculus. This stage was ushered in by the opening of Johns Hopkins University in 1876, by the return to this country of Sylvester after an absence of thirty years, by the migration of a large number of American graduates to Germany for advanced study and their return to professorial positions at home, and by the rise of the critical spirit in all branches of learning. The influence of Weier-

strass and his school was particularly felt in the treatment of the calculus. The older texts with their crude and often erroneous methods found their way into the discard, to be replaced by those in which the logic was at least meant to be irrefragable. One text, quite typical, written especially for engineers, devotes nearly a whole page of closely printed matter to the derivation of the rule for the differentiation of the product of two variables. The page presents a pleasing appearance to the eye, for the symbols are very tastily arranged, but how far the page is a source of light and leading to the sophomore is at least a question. Another very able work, of the same period, devotes several pages to the derivation of the differential coefficient of a logarithm. All may be very admirable mathematics, but it is certainly very questionable pedagogy. Whatever success may have attended efforts on the score of logic, the benefits of rigor were not widely diffused and the calculus continued to be to the great majority of students a terra incognita, and its value in practical affairs unappreciated. The difficulty in accepting the logic of the first period was more than offset by the impossibility of understanding the logic of the second period.

About thirty years ago we seemed to enter upon a third stage, marked by the placing of the principal emphasis upon reality rather than upon rigor. Efforts to make the processes logically rigorous are giving way to efforts to make them real, vivid and vital, and therefore attractive, in the very rational expectation that this is also the surest path to whatever certainty along this line that is accessible to finite understanding. Reliance is put increasingly upon intuition, judgment, exposition and close touch with visible reality. Concrete problems are used in increasing numbers, and there is a practical acceptance of the principle that in the acquisition of knowledge an idea is best grasped when given a visible representation. In recent texts practical problems drawn from engineering sources abound, but the attempt to demonstrate the principle of the calculus deductively has not been wholly abandoned in favor of a purely expository method. We are still in the clutches of the old idea, from which no author has been able to break away to the extent of putting instruction in differentials on the same footing as instruction in logarithms, trigonometric functions, and components of forces.

In these three stages there is, naturally, considerable overlapping. Adumbrations of the present attitude and methods are clearly discernible as far back as the early forties, when Professor Elias Loomis published the first edition of his calculus. Though he, primarily a physicist, had a keen sense for the concrete and practical, he confines himself to illustrative problems of a geometrical character. It was only in a much later edition, under the influence of

Professor H. A. Newton, an astronomer, that he introduced problems from mechanics. The inspiration and model for this work came from an earlier book on the subject by Professor William Ritchie of University College, London, which, by the way, was a work of exceptional merit considered as a textbook. Professor Edward Olney, in the early seventies, published a book on calculus in which kinematic problems were freely used. This work embodies the instinct that had been working in the minds of the teachers of this subject for some years. It was severely criticized at the time of publication because of its adoption of the infinitesimal method. About the middle of the 19th century we had two mathematicians in this country who were in no sense passive imitators in this matter but active and original thinkers—Professor Benjamin Pierce of Harvard and Professor Theodore Strong of Rutgers, the former ably expounding the infinitesimal method of Leibnitz and the latter the purely algebraic method of LaGrange.

A STUDY OF SOME OF THE PHASES OF SHOPWORK AS A PART OF PROFESSIONAL ENGINEERING

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Introduction

The study of professional engineering shop first entails an understanding of engineering objectives; then a knowledge of the present status of the shop laboratories; next, a study and a decision as to whether they are necessary as a means in fulfilling the engineering objectives; and, finally, if found necessary, to determine what manner of shop must be organized and given to help fulfill these objectives. The term shop as used throughout this study refers to the educational content given in such courses, as commonly referred to as machine shop, heat treating, welding, and the like. It may be an engineering shop in which the work may be of the trade type, or it may be one of the strictly engineering laboratory type, where the engineering aspects rather than the trade aspects are emphasized.

Meade says that the field of engineering work includes those branches of technical service and of business and professional work which have to do with the utilization of natural resources for human benefit. The function of engineering service is the adaption of the laws and resources of nature to utilitarian purposes. It involves the active utilization of natural conditions and natural resources through construction.

The aims of professional engineering are sometimes given: first, as the control of nature; second, as the direction of men; third, as the appraisal of values.

The functions of the engineer become; first, the designer; second, the supervisor; third, the constructor; fourth, the operator; fifth, the investigator; and sixth, the adviser. It is the engineer's duty to formulate an ideal and from that ideal, to create a reality.

The engineering colleges are educating for the field of engineering work. They are training young men to satisfy the aims of professional engineering and to perform the various functions of the engineer. Does so-called shopwork have a part, and if so, what part in educating for the above field, and in training for the above functions?

The purpose and scope of this investigation is determined by the preceding question, and by the various conditions which seem to exist in engineering colleges in the field of professional engineering shop. Conditions which prompted the study are as follows:

1. Variation of opinion.
2. Attitude of faculties.
3. Attitude of students.
4. Very few previous studies.
5. Haphazard growth from the mechanics colleges of earlier days.
6. Comparison of vocational and industrial shop education of the secondary grade with the shop of the so-called professional engineering grade through personal observations.

The prime purpose of this study then becomes that of getting the desired knowledge of the present status of engineering shop, and from this study and the engineering objectives, to find a solution as to the place of shopwork in the curriculum if it should have a place, and to determine what manner of shop should be organized and given.

To make certain that the statistical results are reliable, practically the whole population from a statistical point of view has been studied. Therefore the difficulties of random sampling have been largely eliminated. From this total population there has been a return of nearly 70 per cent. The investigation covered 109 schools which were selected after semi-technical schools and a few engineering departments of little importance in this study were eliminated. The 109 schools were divided into 2 groups; those with shop and those without shop as determined by their catalogues. About 4/5 of the group had shop of some nature and the other 1/5 had no shop. There has been an average return of 4 replies per school. Following tables show the excellent distribution of the replies over these 109 schools, every school responding. These 109 schools cover every section of the country, every possible environment, and every size of school giving four year courses. Deans, Department Heads, and Superintendents of Shops were included in the survey. Also to make the picture as complete as possible 18 industries, all large employers of engineering college graduates were asked for their ideas on the subject. The replies give industry's point of view in so far as these industries are concerned. The replies from industry have come from Vice-Presidents, Works-Managers, Educational Directors in industry, and the like.

Four sources of data and information were used in gathering complete facts. These 4 sources were; engineering and college catalogues, the college bluebook, past literature on the subject, and most important, the questionnaire sent to all the schools.

A straight tabulation of the data received was made. The returns named those administrators who in the main decided what shop should be given for each curriculum. These replies were totaled to give the final consolidated results in regard to what shop should be given in each curriculum. Each group of department heads vary very little from the total results as given.

Statistical Results

The following tables give the statistical results.

TABLE 1

Average Hours per Week for One Semester

(Represents total shop given as taken from the catalogues of the 109 schools studied, reduced to a semester basis and clock hours per week.)

	Wood	Pattern	Foundry	Forge	Heat Treat.	Weld.	Mach.	Total
Mechanical Engineering	1.1	2.7	2.8	3.1	.4	.1	8.9	19.1
Electrical Engineering	1.0	2.5	2.1	2.1	.1	.1	6.2	14.1
Civil Engineering	1.1	1.0	.7	1.4	.1	.07	1.1	5.4
Chemical Engineering	.6	.8	1.1	1.2	.03	0	1.6	5.3
Mining Engineering	.9	.1	.9	.9	0	.04	1.2	4.0
Industrial Engineering	.9	1.2	2.1	1.0	.5	0	6.8	12.5
Arch. Engineering	.9	0	.25	.6	.05	0	.05	1.8
Ceramic Engineering	.4	0	.9	0	0	0	0	1.3
Metallurgical Eng.	.7	0	1.0	.8	.12	0	1.2	3.8
Petroleum Eng.	.75	0	0	.75	0	0	0	1.5
Textile Engineering	1.4	0	.3	1.1	0	0	5.4	8.2
Sanitary Eng.	.75	0	.75	.75	0	0	0	2.2
Aero. Engineering	.4	3.4	2.9	2.7	5.2	0	5.2	14.8

TABLE 2

Returns—Schools without Shop

	Sent	Returned	Per Cent
Deans	22	15	68.2
Mechanical Engineering	17	11	64.7
Electrical Engineering	21	13	61.9
Civil Engineering	22	13	59.1
Chemical Engineering	16	12	75.0
Mining Engineering	6	5	83.3
Industrial Engineering	5	3	60.0
Petroleum Engineering	2	2	100.0
Totals	111	74	68.2

TABLE 3

GEOGRAPHICAL DISTRIBUTION OF RETURNS—SCHOOLS WITHOUT SHOP

Region	States	Schools	Returns	
Pacific Coast	1	1	5	
Rocky Mountain	1	1	4	
Middle West–West	1	1	2	
Middle West–East	2	4	14	Avg. 3.5
South Mississippi	1	1	1	
Southeast	3	4	12	Avg. 3.0
East	5	7	25	Avg. 3.6
New England	3	3	11	Avg. 3.7
Totals	17	22	74	Avg. 3.4

Average means average per school.

TABLE 4

DISTRIBUTION OF SCHOOLS ACCORDING TO THE NUMBER OF REPLIES AND THE NUMBER OF COURSES PER SCHOOL—SCHOOLS WITHOUT SHOP

Number of Replies	Schools	Per Cent
1	2	9.1
2	2	9.1
3#	8	36.3
4#	6	27.3
5#	4	18.2
Totals	22	100.0

Number of Courses	Schools	Per Cent
1	0	0.0
2	1	4.6
3#	8	36.4
4#	5	22.7
5#	5	22.7
6	3	13.6
Totals	22	100.0

The symbol # marks those numbers which occur the most; indicating a well balanced distribution of replies with reference to number of courses offered.

TABLE 5

RETURNS—SCHOOLS WITH SHOP

	Sent	Returned	Per Cent
Deans	87	64	73.6
Mechanical Engineering	84	58	69.0
Electrical Engineering	80	61	76.3
Civil Engineering	80	55	68.7
Chemical Engineering	63	45	71.4
Mining Engineering	28	19	67.9
Industrial Engineering	16	10	62.5
Architectural Engineering	21	15	71.4
Ceramic Engineering	6	5	83.3
Petroleum Engineering	2	1	50.0
Textile Engineering	4	3	75.0
Sanitary Engineering	2	1	50.0
Aeronautical Engineering	6	4	67.7
Superintendent of Shops	80	39	48.7
Industrial Section	18	15	83.6
Totals	579	397	68.6

TABLE 6

GEOGRAPHICAL DISTRIBUTION OF RETURNS—SCHOOLS WITH SHOP

Region	States	Schools	Returns	
Pacific Coast	3	6	31	Avg. 5.1
Rocky Mountain	7	9	33	Avg. 3.6
Middle West–West	8	14	77	Avg. 5.5
Middle West–East	5	13	59	Avg. 4.5
South Mississippi	6	11	47	Avg. 4.2
Southeast	7	9	39	Avg. 4.3
East	6 and Washington, D. C.	17	65	Avg. 3.6
New England	5	8	31	Avg. 3.9
Totals	47 and Washington, D. C.	87	382	Avg. 4.4

TABLE 7

DISTRIBUTION OF SCHOOLS ACCORDING TO THE NUMBER OF REPLIES AND THE NUMBER OF COURSES PER SCHOOL—SCHOOLS WITH SHOP

Number of Replies	Schools	Per Cent
1	2	2.3
2	8	9.2
3#	14	16.1
4#	19	21.8
5#	26	29.9
6	11	12.6
7	7	8.1
Totals	87	100.0

Number of Courses	Schools	Per Cent
1	1	1.1
2	0	0.0
3#	14	16.1
4#	33	34.5
5#	17	21.8
6	20	24.2
7	2	2.3
Totals	87	100.0

The symbol # marks those numbers which occur the most; indicating a well balanced distribution of replies with reference to number of courses offered.

TABLE 8

INSTRUCTIONAL AIDS BEING USED

	Text	Notes	Ref. Work	Reg. Lectures	Practical Instruction Sheets
Pattern	10	12	8	14	15
Foundry	12	11	10	10	10
Forge	7	9	5	11	11
Machine	16	15	13	18	18
Heat Treat	8	12	11	11	11
Weld	8	13	7	9	9
Production	5	6	6	6	6

Trips, lantern, special demonstration were mentioned. Total returns for above were (*39*).

TABLE 9

MAXIMUM NUMBER OF STUDENTS PER CLASS PER INSTRUCTOR

Pattern	20–25
Foundry	15–20
Forge	15–20
Machine	20–25
Heat Treat	10–15
Weld	15–20

Classes in general were less than the figures given, being limited by lack of room and equipment. These figures are for shopwork as now given.

TABLE 10

FROM REPLIES FROM MEN IN INDUSTRIES

From 15 of the Large Employers of Engineering Graduates.

	Yes	No
I. Should shopwork be given in any professional engineering course?	13	2
II. Should shopwork be given in all courses?	9	–
(Should be given in M.E., E.E., Ind.E., C.E.)	1	
III. Purposes given:		
1. Study of Materials		
2. To give a practical point of view		
IV. Are these courses the same value as other courses?	7	3
V. Should the shops have direct contact with industry?	7	2
VI. Are the shops one of the best means of coördinating industry and the schools?	6	2

TABLE 11

CONSOLIDATED GENERAL STATISTICAL SUMMARY

		Yes	No
I. Should shopwork be given in a professional engineering course?	(1)	339	119
II. Should summer shop in industry be required?		125	219
III. Is the program so arranged that shop objectives are put into use?		205	41
IV. Should other than mechanical engineering students take shop?		267	22
V. Is shopwork considered of commensurate value with other courses?		150	76
a. By the faculty		161	86
b. By the students	(2)	131	90
c. By the graduates		115	68
VI. Is there any connection between shop and the other work in the curriculum?	(3)	130	101

TABLE 12

SHOP PURPOSES

1. Skill of Hand	101	
2. Appraisal of Values	98	
3. Knowledge of Materials	241	(1)
4. Training of Judgment	144	
5. Knowledge of Design	169	(2)
6. To illustrate fundamental principles of engineering	156	
7. Knowledge of Production and Manufacturing	162	(3)
8. One of the laboratories to apply principles of academic work	103	

Those shop purposes which might be classified as giving formal disciplinary values and not direct values are not considered of the same importance as those giving direct values. According to the latest educational psychology, formal discipline as exemplified by training of judgment is extremely questionable. Such training as received like that mentioned above, would only train shop judgment; and since some, or it may be said perhaps the majority of shops are

far enough removed from industry, that even little such training is actually transferred from the school shop to the industrial shop where it would be used in life situations. To be effective there must be life situations.

TABLE 13

CONSOLIDATED TABLE OF INDIVIDUAL SHOPS FOR EACH CURRICULUM

	M.E.		E.E.		C.E.		Chem. E.		Min. E.	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pattern.....	114	21 (R)	111	70 (R)	34	133	38	105	30	110
Foundry.....	124	16 (R)	122	66 (R)	43	120	60	97	45	94
Forge.....	109	28 (R)	112	68 (R)	54	112	52	103	62	79(E)
Machine.....	136	6 (R)	174	14 (R)	53	113	76	83(E)	59	78(E)
Heat Treat..	116	24 (R)	100	90 (E)	36	130	64	94	54	84
Weld.....	114	27 (R)	110	73 (R)	51	117	55	102	49	93
Production..	64	?71	44	133	14	133	7	143	5	130

	Ind. E.		A.E.		Met. E.		Tex. E.		Cer. E.		Aero. E.	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pattern.....	84	54 (R)	38	99	–	3	1	3	–	4	2	1
Foundry....	92	41 (R)	42	94	2	1	0	4	1	3	3	–
Forge.....	80	51 (R)	41	95	2	1	1	3	–	4	1	2
Machine....	97	35 (R)	43	93	1	2	4	0	1	3	3	–
Heat Treat.	83	49 (R)	37	100	1	2	0	4	–	4	3	–
Weld.....	82	52 (R)	41	93	1	2	1	3	1	3	3	–
Production.	74	?55	13	116	0	3	1	3	–	4	1	2

(The number of schools giving last 3 curriculums is not great.) (Metallurgy seems to be generally combined with mining or chemistry.) Check to determine significant differences is below.

Cases	Numerical Difference	Per Cent of Total	Difference Per Cent	Probable Error in Difference	Chances in 100 for a True Difference
		FOR TABLE 11			
(1) 458	220	26	24	.025	100
(2) 221	41	41	9	.0318	98
(3) 231	29	43	7	.0314	93

FOR TABLE 13

M.E., Min.E., Ind.E., A.E.

125	25	40	10	.0423	95
125	46	33	17	.0414	100

E.E., C.E., Chem.E., and others

150	30	40	10	.0423	96
150	55	33	17	.0378	100

Differences are not checked where the number of cases is less than 25.

Those shops with the differences significantly in favor of shop are marked with an (R) for the required shop and where the difference is not significant in either direction, the shop is marked with an (E) for elective. Those not marked at all are to be omitted as the difference is significant and opposed to the shop. The preceding represents the best composite opinion of nearly 75 per cent of the administrators of the engineering schools, and includes schools with and without shop.

TABLE 14

CONSOLIDATED SHOP COMBINATIONS

Mechanical Engineering	
All courses as listed	43
All courses except production	36
Patt., fdry., fge., mach., heat treat, weld	4
Foundry, fge., mach., heat treat, weld	5
Electrical Engineering	
All courses as listed	19
All courses except production	17
Pattern, fdry., fge., mach.	14
Machine only	3
Civil Engineering	
All courses except production	2
Pattern, fdry., fge.	3
None	28
Chemical Engineering	
All courses except production	5
Fdry., fge., mach., heat treat, weld	3
Mach., heat treat, weld	3
Machine only	5
None	24
Mining Engineering	
All courses except production	7
Fdry., fge., mach., heat treat, weld	6
Fge., mach., heat treat, weld	3
None	25

Industrial Engineering
- All courses as listed 37
- All courses except pattern 9
- None 12

Architectural Engineering
- All courses as listed 7
- None 41
- (A.E. may have been taken for aeronautics in a few cases; however it does not affect the results.)
- All other combinations appeared less than 3 times.

TABLE 15

Combinations Selected for Curriculum Courses

Mechanical Engineering
- All courses with not more than 1 omitted 85
- All others 32

Electrical Engineering
- All courses with the omission of any except pattern, foundry, forge, machine 60
- All others 41

Civil Engineering
- None or not more than 1 course 68
- All others 35

Chemical Engineering
- None or not more than 1 course 47
- All others 41

Mining Engineering
- None or not more than 1 course 37
- All others 33

Industrial Engineering
- All courses with not more than one omitted 50
- All others 24

Architectural Engineering
- None or not more than 1 course 51
- All others 22

TABLE 16

Shop Control Table

Title and rank of man in direct control shops
1. Instructor 35
2. Superintendent of Shops 32
3. Professor 28
4. Head of Mechanical Engineering 28
5. Assistant Professor 23
6. Associate Professor 6

Title and rank of man who controls the shop situation
1. Dean 35
2. Head of Mechanical Engineering 32
3. Head of department concerned 30
4. Committee or faculty 23
5. Professor of Mechanical Engineering 12
6. Dean and Head of Mechanical Engineering 3

Pertinent Quotations and Suggestions Received; the First Series Without Shop, and the Second Series With Shop

In order to show what many engineering educators and some industrial leaders have in mind in the field of engineering shop, the following quotations are given. These statements also help to show the variety of opinion. In many cases they contain helpful suggestions. They are a random selection. They also furnish added data or information which forms part of the background for recommendations.

A. Without-Shop Series

1. *The Deans' Section*

1. May have some practical value but believe that the time could be better spent on theoretical subjects.

2. Too expensive, almost impossible to keep equipment up-to-date, equally difficult to keep processes up-to-date.

3. Shopwork is of high school grade; manual work should be taught in the high school; the college should maintain all kinds of laboratories but not practice shops.

4. Require for entrance or have the technical high school give it in the summer. Too time consuming for a 4 year course.

5. We see no reason for considering this subject any different than any other course in the curriculum. On this basis it should be treated by lecture and text book, with the additional opportunities as may be available.

6. I favor short intensive courses during the summer.

7. The time should be spent on fundamental subjects, there is too little time available now for the four year course.

8. More physics, more chemistry, design, economics, accounting, liberal arts might be substituted for shopwork.

9. While shop knowledge is useful it must be obtained before college or in some intensive way.

2. *Mechanical Engineering Department Section*

1. Time of student should be put to the best use on studies he can not so well pursue outside of college. Shop is better obtained in the summer and after graduation than ever in school. Too expensive to keep equipment and methods up-to-date.

2. A large number of boys can get shop in technical high schools; required to have six months experience before graduation.

3. Can get shop during the summer or after graduation very quickly. Can use the time to better advantage.

4. Should be given in industry.

5. Good courses in various engineering laboratories could replace shops.

6. In my opinion a certain amount of shop training under a competent teacher is a very valuable piece of engineering training.

3. *Electrical Engineering Department Section*

1. Limit the amount to the minimum amount required to acquaint students with tools and processes.

2. Time during the college semester is too valuable to be dallied away in shopwork. Those who intend to go into mechanical engineering or electrical engineering should be sufficiently interested to get shop outside of school.

3. Shopwork in industry is much more profitable.

4. Time can more advantageously be spent in other kinds of instruction.

5. Cognizance of the ability of the student to keep in touch with practical engineering should be taken.

6. There should be more electives outside of engineering.

7. I believe shopwork gives the student something which cannot be obtained elsewhere. For the designer it is necessary. Sufficient work can be given. Success or failure will be determined by the planning of the work.

4. *Civil Engineering Department Section*

1. Space and equipment are too costly; industrial plants are training graduates along shop lines to a better advantage than the schools.

2. Coöperative system of education seems to be the best and modern method of engineering education.

3. In a brief four years there is more important material needing study than the shop courses. Better spend more time on the social sciences.

4. Depends upon the nature of the course.

5. There is no need for shop in civil engineering and it is of doubtful value in other courses.

6. Nothing can replace shop.

7. Require at least two summers of practical work along the lines of the course taken.

8. One of the most valuable courses taken as a student.

5. *Chemical Engineering Department Section*

1. Collegiate education can only stress the fundamentals in this vast subject. To aid adequately too large an investment in equipment would be required.

2. Other activities are more beneficial.
3. There is not enough time.
4. I prefer shop in the regular schedule and six weeks factory work in the summer.
5. Shop should not be given at the expense of fundamental subjects.
6. Personally I think shopwork has little place in an engineering course. Very useful but not a part of engineering education.

6. *Mining Engineering Department Section*

1. There are more important subjects to the mining engineer which are omitted because of lack of time.
2. Actual work on the job is better.
3. I feel strongly in favor of this as colleges can do much to bridge the gap which now exists between the so called fundamentals and their actual application. Certainly shopwork is one of the best places to bring about a connection.
4. I believe that every young man going into engineering should have some shop experience either before or after entering college.
5. There seems to be no good reason to include shop in mining engineering to the exclusion of more necessary subjects.

7. *Industrial Engineering Department Section*

1. We have no shops; I think we should.
2. We strongly advise our students to take up summer work in the industry in which they are most interested.
3. We are short of time for intellectual development.

8. *Petroleum Engineering Department Section*

1. Already filled with required subjects and too inelastic.
2. Have field work in the oil industry.

B. With Shop Series

1. *The Deans Section*

1. In general I believe too much emphasis has been given to shopwork, and possibly the kind of work given has not been of the best. On the other hand to eliminate them entirely would be a serious mistake.
2. Do not think industrial shops are a full substitute.
3. Nothing takes the place of shop laboratories for instruction and experimental phases. No school shop can show varied applications like industry can. A combination of the two is the only solution.
4. Think shop is desirable.

5. Don't replace them.

6. Nothing can take their place.

7. I am strongly of the opinion that the time of students is too valuable to be spent in shop—it is impossible to have the tools or methods of industry, and when that is admitted the argument for shop falls, because they have learned something of no practical value.

8. Suggest in place of shop a shop "clinic" demonstrated lectures with notes and collateral reading with shop time reduced to one period per week.

9. Would suggest better shops.

10. I believe the time is coming when state schools will have to take over the function of semi-technical education.

11. Not long ago, I was in a certain college machine shop that looked splendid to me. There were perhaps 50 machines of various kinds. A gentleman, an alumnus of the college, was with me. I said it looked nice. The reply was, "Oh yes, but I happen to be in that business and there is hardly a machine that would be tolerated in any plant. They are all antiquated."

12. We are of the opinion that shop should be used to illustrate production problems and to aid in developing an appreciation of the relation between design and manufacturing processes.

2. *Mechanical Engineering Department Section*

1. The pattern shop has been eliminated and only a few representative machines have been retained. Similarly only typical machine tools, illustrating shop methods, time study, and materials handling will be used to illustrate this phase of machine shop practice.

2. We believe that students learn about 3 times as much about patterns as we now teach it than when he did the manual work in the laboratory.

3. Would suggest nothing in place of the shop laboratories.

4. Nothing should replace the shop laboratories.

5. Summer courses in industry might replace shop but they are hard to arrange.

6. Would suggest more work in metallurgy.

7. Work in industry might be better if it could be chosen and directed.

8. Every student should engage in some outside technical employment during his summer vacations.

9. The shops are made the center of a group of student self-help industries employing student labor.

10. The foundry is run about 2 months a year on strictly production.

11. There is not the correlation there should be between shop and the other work in the curriculum.

12. The student should not receive instruction detrimental to his ambition to study theory.

13. Shop instructors should be technically trained men.

14. Some effort is being made towards methods of procedure and away from mere exercise work.

15. It is possible that the entire method will be changed so that shopwork will be combined with metallurgy and materials testing, thereby comprising a comprehensive course.

3. *The Electrical Engineering Department Section*

1. More time should be spent in science and mathematics, and their application.

2. There is no equivalent possible.

3. Shop should be given to students who have not had the equivalent elsewhere. If the student cannot get shop in summer employment, an opportunity should be given at the university as an extra subject.

4. More time should be spent on fundamentals.

5. All engineering students should have a working knowledge of different types of standard commercial machines as found in machine shops in order to be able to direct repairs, design, and construction of a varied nature.

6. We believe in shop experience in school and in industry.

7. A real difference of opinion exists as to the value of shop courses. It is safe to say that many of us outside of the mechanical engineering department are 'on the fence.'

8. The question of commensurate value is a hard one to answer. A few students are shop men. Except for mechanical engineering I do not think that the faculty pays much attention to the shopwork. Shop instructors are not college graduates.

9. I believe some shopwork is necessary to compel coördination of hand and mind. Universities are prone to the giving of trade school shop courses. The trade schools want to move into the university class. Each should stick to its own field.

10. Am in favor of shop when the emphasis is placed on the engineering aspects instead of skill.

11. Too much detail is paid to details pertaining to manual dexterity and not enough to the problems pertaining to the relation between production and design.

12. Students often complain that the material content is too low; that there is not enough education per hour spent in the shops. This can be controlled by the nature of the work given. Turning down a long shaft for instance involves little education after the first few minutes of the operation.

13. Instructors are just practical mechanics.

14. As now taught shop is of little value because here as in most engineering colleges the old type of instruction is given.

15. I am enthusiastic about shop as training for all engineering.

4. *The Civil Engineering Department Section*

1. Should give courses which have a more direct training or engineering value to the student.

2. Nothing should nor can replace them for the purpose they serve.

3. There are dozens of better subjects for civil engineers.

4. I know of no proper substitute for them.

5. There are so many subjects more important to the civil engineer and any of them would do.

6. We do not require shopwork in our civil engineering and have not for years. I'll admit I'd like the fellows to have it but I believe other things are more important for the work they are going to do.

7. I had no shopwork of any kind and often feel the lack of it. I am not sure but what our students get a little training in shop that they never get elsewhere and believe it is good for them.

8. We used to require certain shop courses. We came to the conclusion that these were of little value to the civil engineer.

9. I would make shopwork optional for all except mechanical and electrical engineering.

10. We have had a full curriculum for the last 10 years without it.

11. There should be a well defined connection between the shops and the other work in the curriculum.

12. We do not require shopwork in either sanitary or civil engineering.

5. *Chemical Engineering Department Section*

1. They have the notion that shopwork is to teach a man to run a lathe or forge or something like that.

2. If shopwork were eliminated its equivalent should be embodied in chemical engineering laboratory.

3. Shopwork should be required for entrance credit. More time should be given to fundamental science and engineering.

4. A technical man should be able to construct his own apparatus if necessary. Should be able to supervise the work of others.

5. Shopwork is not included nor is value of shop as important as many other subjects that can not be included because of lack of time.

6. We would give more shop if time were available.

7. Our experience has been that the chemical engineer needs shop less and less.

8. Shop is all right if in the hands of competent teachers.

9. If students learn nothing else than the proper care of tools, shop is worthwhile.

10. Always one may expect an objection to be raised to a course calling for manual labor. But it is nevertheless and for that, my reason, of value.

6. *Mining Engineering Department Section*

1. When we altered our course 3 or 4 years ago, we cut out shop entirely—we did not feel we could give the most essential subjects the time they needed.

2. I think shop is desirable. We included it until a few years ago it was dropped to lighten the schedule.

3. Fundamentals should be given in place of shop.

4. It is considered a desirable elective.

7. *Industrial Engineering Department Section*

1. We try to coördinate shopwork with the other work in every possible way.

2. There is nothing that can take the place of them in imparting the fundamentals of manufacturing.

3. Many opponents of shop instruction fail to realize its intangible values and aid in grasping other subjects.

4. There is no substitute.

5. I have many times heard important employers say they like our graduates because they are so practical which undoubtedly applies to other schools giving shopwork.

8. *Architectural Engineering Department Section*

1. The students are not required to take shop and I do not feel any necessity for the same.

2. It would be of doubtful value.

3. Materials testing is the only thing that might be given to architectural engineers.

4. I fail to understand why college credit is given for shopwork. Most of the courses can be taught in a vocational high school.

5. We have not required shop courses for years.

9. *Ceramic Engineering Department Section*

1. I doubt if work equivalent to the college shops can be had in the summer.

2. We require no shop in ceramics.

10. *Metallurgical Engineering Department Section*

1. For metallurgy I think shop should be required.
2. Much use is made of our shop laboratories in research work.

11. *Superintendent of Shops Section*

1. The chief argument in my opinion for the retention of shop in American colleges appears to be the general lack of any kind of engineering experience of the average college boy.
2. My opinion of shopwork is that we should have but 2 divisions and should call them wood trade and metal trade. Under each we should subdivide according to present day industry.
3. There is considerable difference of opinion amongst students and faculty as to the value of shopwork. If carried out at all, it should be done very thoroughly.
4. Shop laboratory is essential to the training of engineers. It is the type of laboratory that is important.
5. It is often true that the laboratory work instead of being definitely outlined to teach particular principles is dependent upon the experience and training of the individual who is head of the department.
6. It should be possible to attain a higher rank.
7. Considerable commercial work is done by the shops.
8. Let's improve them but keep them.
9. All engineering graduates should be handy with tools.

12. *Industrial Concerns Section*

1. Personally I feel very positive that shop should be retained as a part of professional engineering. I believe that an engineering education should be a solid foundation of science and mathematics, combined with a physical capacity to do good work and a character to direct the whole toward a definite ideal or objective.
2. Generally speaking I would give a certain amount of shopwork to all engineering students. It furnishes a series of practical situations which call for accuracy and neatness, competence, and an appreciation of skill even if not skill itself.
3. On the whole I think the great advantage of shopwork is that it gives a practical point of view which is a salutatory thing to have along with the great amount of theoretical training which of necessity makes up the schedule.
4. The greatest handicap of a professional engineer is the fact that he has not had practical work.
5. I don't see how anything else can take the place of shopwork.
6. The shops are the only place where a man can get a real value of time and labor.

7. Better coördination is brought about through the proper selection of instructors and Professors, selecting those who have had considerable practical experience.

8. I think shop courses if properly given are of the same value as other courses.

9. Too great a percentage of engineering graduates do not know how to work.

10. A theoretical engineering course would not turn out a practical engineer who can talk the language of the fellow with whom he must deal.

11. Nothing can equal shop training in value to the student.

12. Anything that you can do to give him this experience will work to the advantage of the student and industry.

13. Shopwork need not be given in an official engineering course, though it is exceedingly desirable as a summer experience or as a part of graduate training.

14. The student should take shopwork as early as possible in his studies.

15. Most of our people who are in touch with educational work feel that shopwork in the college is not especially profitable.

16. It is especially difficult for Professors in engineering colleges to keep abreast with developments in industry and it is practically impossible for them to appreciate the necessity of production meeting schedule dates, and securing workable results. A man who does not have this point of view can not teach it to others.

17. I believe all engineering students should have shop but should have less of the old time trade training that was common in technical schools 15 or 20 years past.

18. The shops should provide a laboratory where the student can crystalize his ideas as to the practical applications of his engineering education.

The above comments come from men in industry who are Vice-Presidents, Works Managers, Educational Directors, and the like.

The men in industry are in the practical work. Naturally they are inclined to emphasize the practical. The men in college are to a large extent giving theory and are more academic minded. Many of the latter have a practical viewpoint and many do not. Those inclined towards theory think theory should be given. Industry gets the graduate and finds that he is unable to apply his theory to the job. They favor more practical work. The writer agrees with the men in industry. There should be plenty of theory but that theory in order to be of the most benefit to the student must be used by him in actual life situations that should be produced in his college course in the various subjects.

While all the preceding quotations may show a wide variation in

opinion, it must be kept in mind that these quotations have no connections with numbers actually in favor of a certain point. There may be very few or there may be very many in favor of a certain point. The statistical tables give the numbers for or against certain major propositions.

Summary and Conclusions

The following conclusions are drawn from the data.

1. It appears that engineering educators believe that there are valuable contributions to engineering education contained in shopwork, and that it should not be dropped from the curricula.

2. Summer shopwork while desirable should not be required.

3. Very little has been done in the semi-technical field which includes training for chemists, draftsmen, and the like.

4. The following should be shop purposes for all courses giving shop unless excepted.

a. To give a knowledge of materials.

b. To give a practical knowledge of design.

c. To give a knowledge of production and manufacturing.

Exceptions:

Chemical Engineering.

a and *b.* As above.

c. To develop skill of hand.

Industrial Engineering.

a. As above.

b. To produce illustrations and applications of principles of academic work.

c. To give a knowledge of production and manufacturing.

5. Other than mechanical engineering students should take shop.

6. Shopwork in the majority of cases is considered of commensurate value (if properly given) with other courses. However the attitude of the students seems to be less favorable than that of the faculty and graduates.

7. There seems to be quite a lack in connection between the shops and the other work in the curriculum.

8. Objectives appear to be partially put into use.

9. Full use of the various instructional aids is not made. The use of any particular type is small.

10. Lack of equipment and of room is the most common factor in determining class size.

11. The industries replying were, as a group, decidedly in favor of shop.

12. Evidence points to the fact that there should be a desirable amount of shopwork in mechanical, electrical, and industrial engineering. It also points to the fact that there should be very

little or no required shop in civil, chemical, mining, and architectural engineering. Metallurgy appears to be in the same class as mining and chemical engineering. Ceramics is in the same class as civil engineering, and textile and aeronautical engineering seem to line up somewhat with the first mentioned group in that some shop should be required.

Discussion of Results

The data unquestionally point to the fact that there are valuable contributions to engineering education contained in shopwork, and that it should not be dropped from the professional curricula.

A knowledge of this field is necessary if engineering objectives are to be fulfilled. Utilization of natural resources means change of state, means manufacturing with all of its ramifications, means a thorough knowledge of operations, materials and processes.

The selective utilization of natural resources through construction involves shopwork. The control of nature means changing which again involves the fundamentals of shopwork. It is hard to conceive of shopwork as not entering into the functions of engineering. The designer must thoroughly understand shop, the supervisor can not supervise efficiently without its knowledge, the constructor and the operator use its fundamentals first hand, the adviser can not intelligently advise unless he understands its underlying fundamentals. It is the engineer's duty to formulate an ideal. That is theory. But all that work is waste unless from that idea the engineer can create a reality. The creation of the reality means fabrication, leading back again to a more or less extent to shopwork fundamentals. Since engineering colleges are trying to meet the above situations, to train engineers to perform the above functions and duties, it means that if shopwork is put aside, they have created a gap in the engineer's education and since shop and its fundamentals play such an important part in so many branches of engineering, it behooves the engineering educator, not to operate and cut out shop, but to use corrective measures of less violence and make the shop situation a healthy one, one in which it is performing its particular function to the last point.

This conclusion does not imply that the usual type of present day shop is satisfactory and is fulfilling educational needs.

There are several reasons why summer shop does not prove a substitute. Reasons are; difficulty of student placement, lack of money for proper supervision, lack of supervision, the type of work generally open for summer employment, and the difficulties of supervision and coördination in conjunction with the industries, which naturally are business institutions and not educational. In general, it may be said that only if it is possible to supervise properly

the shop given is it desirable. It appears from the data that the majority of schools without shop favor required shop in industry which would mean that they think there are educational values in shop.

Nothing should replace shopwork, but it should be thoroughly revised and reorganized to be of full educational value for professional engineering education. It must be brought up to the professional level and cease to be a trade training. Real objectives must be put to work.

While very little has been done in the field of semi-technical education, which includes training for chemists, draftsmen, surveyors, foremen, and the like, something should be done, particularly as long as the selection of engineering students is the chance method as it is at present. Reference might be made to Lehigh University's system. The writer believes their arrangement holds great possibilities. Generally in engineering schools the first two years are fundamental years of preparatory work, and the technical work starts at the third year. Therefore in order to make those first two years as valuable as possible to everyone concerned they should be so arranged that in addition to preparing the student for his more advanced technical work, they should give at the same time the most valuable and usable training for those who are eliminated during those years. The ideal would be to carry each student to his best level and send him out into industry successful as far as his education is concerned.

In order to start on any program, it must be known what is trying to be done by the inclusion of each phase of engineering education. The tendency seems to be a lack of knowledge of concrete direction or of having so many paths or objectives that the guide or instructor is lost in the maze. It is the writer's personal belief and experience that when the number of objectives for one course gets beyond three, the situation begins to get to a point where there is no more effective guidance than if there were none. Out of these three, it is still better if one is paramount. Then a definite path and procedure is pointed out. Sometimes other purposes may be worked in incidentally. There is the opportunity to bring in more desirable incidentals by different organization and still travel towards the definite objective.

The paramount purpose of engineering shop appears to be to give a practical knowledge of materials, perhaps with emphasis on the practical. The other two most important objectives become; a knowledge of design, and a knowledge of production and manufacturing. Meeting these objectives means also meeting engineering objectives and functions. All other items should be subordinated to the above three. Skill of hand should be entirely

incidental except in special cases. Those purposes which tend towards formal discipline can be put aside.

Perhaps the training of practical judgment should rank high as a purpose. However as a means of expressing a purpose it is too intangible. Therefore it has not been listed of prime importance. The writer believes, however that as a course is organized in detail that incidental items might be brought up with course details. For example, with each detail put into the course the question might be raised; does this way lead to a real development of practical judgment or does some other way do it better? If the question is satisfactorily answered, then the incidental may be brought in to some advantage.

Other than mechanical engineering students should take shop. If for no other reason than that so many engineering graduates follow some other work than their own studied course, and since industrial work comprises such a large proportion of available positions, the majority will gravitate into positions where knowledge and education received in proper shop courses will be as valuable to them, if not more so, than any course they could have taken.

The fact that other than mechanical engineering students should take shop does not imply that subjects vitally important to the curriculum should be dropped to give shopwork. But since a scheme of guidance is as little developed as it is and many get into courses where they do not belong, and also since many are advocating a more general course embodying fundamentals, the writer believes that shop through electives should be open to all, who may desire to take it.

The writer agrees, in part at least, with some of the men in industry who replied to this study, that shop should be given but it is not so important what shop, as the fundamentals are or should be embodied in the various shops. Therefore where differences have not proved significant, the shop is not included or is elective. The only shop which appears in universal disfavor is the production shop. The reasons for this are undoubtedly the expense and the difficulty in giving such a shop. This type of shop to be effective requires a much higher type and broader vision than the average shop instructor seems to have. However with proper material and organization the features of production can be very aptly illustrated in the various shops where desirable.

The adverse part of the faculty and particularly the student has to be convinced of the value of shop to himself as a graduate engineer. The writer believes that the changes recommended and a proper program by the shops divisions will convince the student of the value of shopwork. He not only has to be convinced but he has to be kept convinced. A good many students lose their faith in

shopwork after they get into the courses as now given. No course performs its full value unless the student is convinced of its value to him.

At present there seems to be quite a lack in connection between the shops and the other work in the curriculum. The writer is inclined to think that in many schools reporting connections the connection is more theoretical than actual and vital. There should be a well defined connection between the shops and the other work in the curriculum.

The shops should in part at least form a transition from phases of chemistry, physics, strength of materials, metallurgy, and so forth, to engineering subjects such as design and the like.

In general the reports stated that objectives were put into use. While it may be considered presumptuous to say so, here again the writer thinks the situation is more theoretical than actual, as personal observation in many cases has verified such a statement. Many instructors seem to have a rather slight conception of what they are driving at other than trying to teach a trade. Some have the added perception of appreciation. While not intending to reflect upon the old time shop instructor who still appears to dominate the shop instruction in engineering colleges, the writer feels that, since they are only expert mechanics, and since many have passed the stage of being progressive, they are, in general, unable to formulate shop course programs putting objectives to real active use.

All shop instructors should be technically trained engineering graduates with two or three years of industrial experience, and if possible good mechanics, but not necessarily journeymen. And naturally he should be able to teach and understand educational problems. The writer feels that if there is any discrimination, it requires a man of higher caliber in shop than in the academic work.

In opening the way to a higher class personnel in general, the salaries and titular rank should be as high and as accessible as in any other division of the engineering college.

Diversity of results in the use of instructional aids indicates a lack of general thought on that side of shop courses. Certainly instructional aids of certain kinds ought to be in broad use. Lack of the use of aids, lack of engineering purposes, lack of organization, lack of an educational consciousness, have all contributed to shop deficiencies. There are a few shop departments however, apparently not lacking universally in the above deficiencies and they seem to be far in advance of the others. These are only a handful. The writer feels that student attitude on shop not being worthwhile has been promoted by the above deficiencies.

The factors given for class size were lack of equipment and lack

of room, yet course organization will partially mitigate for the material lack. Material lack can at least be partially compensated for, but lack of proper personnel on the instructional staff can not be compensated for. A high type of instructor and poor equipment will do decidedly more effective work than a very poor instructor and excellent equipment. In the writer's opinion also, course organization has more to do with class size than any other one factor. It allows for much better instruction, a better proportioning of the instructor's time, more initiative on the part of the students, at the same time it gives much more effective use of the equipment and therefore it allows much larger classes, cutting down the instructional cost.

The opinion of those in industry should carry considerable weight, as it is in industry that the engineering graduate finds himself upon graduation. Since all these men in industry who coöperated in this study are all in positions in which they have a bird's eye view of their college employees, their opinions should be still more valuable. They were decidedly in favor of shop of some kind.

In conclusion, shops should be retained but should be made educationally effective in professional engineering education. The next division on recommendations contains the writer's present best judgment as to how this may be effected.

Recommendations

It perhaps might be mentioned here that a curriculum analysis, following Bobbitt's or Charter's suggestions, would start as a form of analysis of the life situations in professional engineering in practice. To make the analysis complete there should be a study of each branch of engineering as civil, mechanical, and so forth. From this study the aims could be formulated and material content determined. Such a study would naturally give the shop material for the various curricula as accurately as it could be determined. The study would also, perhaps, help determine the amount of shop. Since the time and cost of such a method would be prohibitive, a different method has been used. This method, while perhaps not as basically sound as the method above, still should give some usable results. While the method used is not the ideal, it is practical.

In making recommendations for shop improvements the following considerations will be taken up: first, the general plans that may be followed; second, those curriculum courses in which shop is recommended; and third, the shop courses that are recommended for the various curricula in which shop might be given. The selections of the first are based upon the writer's understanding

of the previously mentioned objectives. The selections for the last two are based upon the statistical returns.

There are three plans that may be adopted, and any one of these three, it seems, meets both educational and engineering purposes. These three methods are exclusive of various systems of coöperative education. These three plans are as follows:

1. Required high school shop, followed by professional shop laboratories in the professional school.
2. Required summer shop, either in industry or the school shops, followed by professional engineering shop.
3. A regular production shop as a laboratory.

While it is not the purpose of this article to go into a complete program, nor to go into the detailed application for what is considered true engineering shops, yet a few points may be mentioned to explain the above three solutions.

Shop as now generally given is a high school subject. Furthermore, the writer has seen many high school shops that are doing a much better job in teaching shop than the average engineering shop, as now constituted. And surprising as it may seem, the instructors seem to be of a higher caliber in general, particularly in the so called technical high schools. This has been brought about by the raising of the standards for high school instructors and also through the Smith-Hughes work. With this situation, the place for regular shopwork of the trade type is in the high school and not in the engineering school. Shop is accepted for college entrance credit now at many of our best schools, although it is not required. Shop should be set up as one of the entrance requirements. These requirements should help the development of school shops in those schools in which shop is not now given or improve those already in existence. Other benefits to the high school curriculum and social atmosphere could be mentioned here but that is another subject.

To take care of those students who are unfavorably situated in regard to secondary shop, the second plan is recommended. If a student is able to get the right kind of shop training during the summer, this should be substituted for the requirement. This shop, however, should be of the right kind and only accepted upon adequate proof that it is the right kind. Requirements should be set up so that the student would know ahead of time just what type of shopwork would be acceptable. Since by far the majority of the professional schools have shops of some sort at the present time, they should be retained as they are until such time as the high school programs call for shops. If they are following educational development, the suggestion of required shop for engineering should not set up any hardship. Such development should be encouraged

by the engineering schools. When the development becomes practical there would be no further reason for the engineering school to have shops as now constituted. It might be added that secondary shop helps meet the seven cardinal principles of secondary education as much or more than most subjects now in the curriculum. In order not to crowd the program in engineering, the shop as retained, to be given to those unable to get the shop in any other way, should be concentrated in the summer term. In some cities the student is able to take shop in the summer in the local high schools.

The engineering shop laboratories would be given during the year as a part of professional engineering education. These laboratories would be quite different from the traditional type. The development of a proper lecture and demonstration laboratory, which would constitute the shop laboratory would be the center of the course. The writer has seen such laboratories in conjunction with the traditional shop, which if developed would certainly fulfill the needs of professional engineering shop. At present this auxiliary room occupies a rather inferior position in the shop plan. The summer shop or the high school shop would give the necessary preparation to the student so that he might profit to the best advantage from the professional course just as high school mathematics and science furnish or are supposed to furnish a background for other work in the curriculum. This type of course would not necessitate the large investment in machines, tools, and floor space. Also the size of class could be much larger. While more money might still be spent over a standard academic course, yet the shop cost should be reduced considerably. The amount of machinery required, the space, the operating expense would be much less. Money formerly spent on a large number of machines could be concentrated on single up-to-date machines since only one machine of a representative type would be required. No attempt should be made to cover special machinery except as an important part of class room instruction. A study of a group of industries might be made to determine what type of machines are more or less universally used and only universal machine types should be considered as laboratory equipment. Also having only single machines, there should be the better opportunity of disposing of these machines and replacing them when necessary to keep them up-to-date. Every industrial concern does not have so called up-to-date equipment. If it is cheaper to keep the old, the old will be kept. The writer has seen plenty of old equipment in use in actual plants, and these plants were progressive if profits under modern competition means progressiveness. However, the producer that is awake keeps his finger on costs and as soon as the facts indicate a new method that is

much cheaper, that method comes into use. Many concerns have become bankrupt because of the inadvisable buying of new equipment. The same fundamental considerations hold for the school laboratories. The criterion is different in that in industry it is profits and in the schools it is educational values, as partly determined by industrial development.

The aids in a course of the kind mentioned above would be: texts, notes, lectures, demonstrations (by instructor and students), problems, moving pictures, slides, supplementary material, group conferences, and tests. One large lecture and demonstration room for one hour a day for three days a week or whatever time is advisable for particular courses, with groups of any desired size, is all that is necessary with the right caliber of instructor and course organization based upon the objectives, for giving a real professional engineering shop laboratory course which would be far more valuable educationally to the engineering student, would require less equipment, and eliminate equipment that may be good but idle most of the time. Idle equipment is useless and wasteful.

While the course organization, aids, materials, and the like are important because they may determine success or failure, it is not the purpose here to give all those details of application, many of which might happen to differ somewhat in different situations.

The three preceding paragraphs merely suggest what is included in the engineering shop laboratories. It is an engineering course and not a trades or a modified trades course. It must be remembered that the regular shop course provides a background for the engineering course.

In the small engineering school a general laboratory for all shops might be included in one. In the large school each shop might have a special laboratory. The above types would help take care of the number of students, help keep expenses to a mimimum, and help use all equipment to the best advantage.

The third plan of the three would be the best one of the three were it not so difficult to operate it. Some state laws would prohibit a true production shop. The writer feels that while some schools have shops classified as production shops yet it is impossible to have such a shop unless it is made a real business. There is no reason why a real commercial shop cannot be built up and maintained providing there is a high enough caliber of man to develop such a shop. If we are to have a real production shop there must be outside orders large enough or enough orders of small size to operate the shop. Where the commercial shop is prohibited, plan 1 or 2 is recommended. In building up a commercial shop, the purpose of the shop would not necessarily have to be self-supporting, however if the business could be obtained to make it so, it should be.

The writer has thought of one market that might be tapped in some states. From the elementary school through the state university is the complete range of public education. A market could be built up for furnishing various requirements to the schools inside the state at cost. This would mean cheaper buying for the schools, at the same time providing the best type of laboratory. The writer even sees no serious objection to paying students on an incentive basis for what productive work they actually did. This type of shop organization would supply a real life situation. A type of program could be worked out whereby the lower classmen would furnish the lower types of experience and work, all of which are foundational. The functions of management could be delegated to the upper classmen who had shown their abilities. They already run large newspapers and in some places actually supply the town in which the school is located. They do other things of equal worth. Therefore while the above shop would be a new application, the basic idea would not be new. It would bring in many other engineering functions which would be operating under life situations. The medical men have their hospitals; why not give the engineers the same type of advantage. The development of such a plant would bring in many things, which, the engineering student at present can only read about or hear a lecture on and then forget. Power problems, power transmission problems, design problems, manufacturing problems of all kinds, even marketing and distribution problems would arise. It would be a real laboratory. While the general comment on the above solution will be that it is impossible, it is only so because it is looked at on the basis of the past and not the future. The development of such a laboratory, again first of all comes back to the capabilities of the individual doing the job and the coöperation he is given. While such a laboratory would require time in building it up, yet when the job was done, that school could boast of having the best engineering laboratory in the United States. There are many ways and means of working the above plan and getting it into operation. While it offers by far the most difficulties, it also offers the most opportunities. This laboratory could also be used as a research and experimental laboratory by those students and others who might be particularly interested in the problems offered.

Again it should be stated that the courses should be organized around the three objectives as given under conclusions.

The following list gives those curriculum courses in which shop is recommended. This list is not based upon personal judgment but upon statistical results. Significant differences are used in choosing shop courses. The assumption is made that the consensus of opinions obtained constitutes a valid basis for curriculum con-

struction. Since unless plan 3 is adopted there can be no production shop, it is omitted. Production study comes in as one of the objectives in the previous mentioned laboratories. It is believed that production can be studied as well in the new type, and perhaps better than with the standard shops. In no case was the difference significantly in favor of a production shop.

The following tabulation gives the curricula with their shop courses as recommended from the statistical study. (As taken from the consolidated table for the principal curricula.)

Engineering	Pattern	Foundry	Forge	Mach.	Heat Treat.	Weld
Mechanical	R	R	R	R	R	R
Electrical	R	R	R	R	E	R
Civil	—	—	—	—	—	—
Chemical	—	—	—	E	—	—
Mining	—	—	E	E	—	—
Industrial	R	R	R	R	R	R
Architectural	—	—	–	—	—	—

The following is from department head data only including all department heads in their respective departments.

Engineering	Pattern	Foundry	Forge	Mach.	Heat Treat.	Weld
Mechanical	R	R	R	R	R	R
Electrical	E	E	E	R	E	R
Civil	—	—	—	—	—	—
Chemical	—	E	—	R	—	—
Mining	E	E	E	E	E	E
Industrial	R	R	R	R	R	R
Architectural	—	—	—	—	—	—

The following is taken from those department heads only who were in favor of shop.

Engineering	Pattern	Foundry	Forge	Mach.	Heat Treat.	Weld
Mechanical	R	R	R	R	R	R
Electrical	E	E	E	R	E	R
Civil	E	*E*	*E*	E	E	*E*
Chemical	E	E	E	R	E	E
Mining	E	*E*	*E*	*E*	E	E
Industrial	R	R	R	R	R	R

R means required.
E means elective.
—Means no shop either required or elective.
R or *E* means appeared of most importance.

The class sizes that were given as the best for the present type of shop do not apply in the new type of recommended shop. No recommendations are made in regard to the size other than to comment that the class size would be determined by the same factors that determine any other academic class size.

For the hours per week for one semester that each course should have, also no definite recommendations are made. Table 1 gives the average hours per week for one semester for all courses. Since there is a wide variation in the number of hours required at the various schools, the number of hours is indeterminate except for the average and since no more reliable figure is at hand, the averages have been given. This again applies to the old type of shop. It appears from a personal study of the time required by the new type that it will be close to that required at present but probably with a different distribution over the week. The course organization and other such features will have an influence on the time required. Therefore it becomes largely a matter of application.

In closing, the writer feels that the problem has not been completely solved. But he hopes that some avenues of approach have been created, from which a better and sounder shop policy may be developed, and this in turn will lead to the development of the best possible type of professional engineering shop laboratories, laboratories that are *engineering* laboratories and not just trade shops which they seem to be in practice and operation.

COMPREHENSIVE EXAMINATIONS IN THE DEPARTMENT OF ELECTRICAL ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

The comprehensive examination as conceived by the Department has four distinctive features: (1) the examination is one covering electrical engineering as a professional field rather than one dealing principally with the details of individual subjects or comprehensively with any one subject, (2) the examination consists therefore primarily of a number of questions (perhaps ten for any individual student) of a semiproject nature each more or less comprehensive in itself, that is, in one problem may be involved the application of principles of mechanics, thermodynamics, hydraulics or economics, as well as principles of electricity and magnetism, interwoven in the fashion naturally found in practice rather than artificially isolated, (3) adequate time (the major portion of two weeks) is allowed for preparing the answers so that they may be the result of reflection and mature thought rather than of hasty and incomplete analysis, and (4) an oral session is held subsequent to the reading of the papers, at which time the examiners may question the students further as a consequence of the written answers given, following which general discussion relating to the examination problems and to the summing-up of the purposes, utility, and success of the examination procedure is in order.

The examination is set by a committee consisting of three members invited from industry and other engineering schools and two members selected from the Department staff. It covers all of the professional work of the junior and senior years together with its scientific foundation. It is designed to test the understanding of principles and the ability to carry the reasoning therefrom through to a finish, rather than the ability to solve problems by analogy to familiar classroom or textbook forms. Emphasis is therefore placed upon analysis and judgment rather than upon memory. Reference is permitted to texts, handbooks, periodicals or any other sources of information desired, though each student's work must, of course, be individual.

Though the examination is comprehensive in scope, it should not be thought of as general or superficial rather than exact and searching in nature. The problems appearing in it require a deeper understanding of basic principles and more exacting analysis than those in the usual term examinations.

The use of comprehensive examinations in the Department has

thus far been limited to the students of the Senior Honors Group, which averages about eighteen men per year and varies from class to class from about ten to twenty-five.

The Honors Groups are formed at the end of the sophomore year for those students having appropriate scholastic records and personal characteristics, and are carried through the junior and senior years. With consent of the Faculty, the students in these groups are free from the routine of class attendance and solution of repetitious practice problems in all of their subjects and are encouraged to work upon problems of an investigative nature in the laboratories rather than to adhere to conventional weekly assignments. The time freed by this arrangement, which is very considerable, and the more effective use of time which it allows, provide opportunity for reading and reflection related to the subjects of the curriculum, for the purpose of deepening the understanding of and perceiving the interrelationships of the subjects of the curriculum; and also for a certain amount of general reading which may unfold a view of the importance of engineering education and practice in the modern social order. This encouragement of individual work by lessening the demands of conventional hours, is a primary object of the honors group plan. As an aid to carrying this out, certain staff members are designated as conferees or counselors for honors group students. However, one of the important factors in accomplishing this correlation of subject matter so that the field of electrical engineering is viewed as a whole, is the comprehensive examination, the importance of which has been increased each year since its initial trial for the class of 1928. While the comprehensive examination serves also as a measure of achievement, its chief purpose is to exert an influence upon the habits of study of the students during the two-year period of honors group work.

In general, honors group students are held responsible also for the usual written quizzes and term examinations,* except in the second term of the fourth year. In that term they are released from all final examinations and intermediate quizzes in favor of and to provide time for an adequate comprehensive examination.

Though the comprehensive examination has been employed only for students of the Honors Groups, the plan is not carried on as an isolated feature of the Department's processes. It is carried on in association with and gains considerable support from the practice of grouping the students into small teaching sections, in accordance with their observed mental speeds and capacities, so that each

* As a special test case, one well qualified junior has been granted freedom from examinations and intermediate quizzes for most of the two years of honors study, at the end of which time he will be given a comprehensive examination especially designed for him.

student finds himself in a group of relative mental homogeneity in which the mode of instruction is designed to meet his needs. The arrangement is flexible, however, for a student may be transferred from one section to another or may be given the opportunity of becoming an honors group student, in accordance with his progress and performance. Hence the comprehensive examination is a potential influence upon every scholarly and ambitious student in the Department.

The examiners chosen for the Honors Group of the Class of 1931 are Mr. O. B. Blackwell, Transmission Development Engineer, American Telephone and Telegraph Company; Mr. F. M. Carhart, member of the firm of Jackson and Moreland, Consulting Engineers; Professor F. C. Stockwell, Anson Wood Burchard Professor of Electrical Engineering at the Stevens Institute of Technology, and Professors Dahl and Fay of the Department staff.

The results of the comprehensive examination as a measure of achievement have been very good. Though no formal honors are awarded to students whose comprehensive examinations are of high quality, most of the papers have been very satisfactory, and none could be considered failures. While the present status of the comprehensive examination is of too recent date to permit conclusions to be drawn relating to its influence upon habits of study, the situation is very encouraging. The first two years in which comprehensive examinations were tried, the honors group students took them voluntarily in addition to their other examinations, as a matter of interest in testing themselves, and to coöperate with the Department for the purpose of experiment. The students do not, in general, fear the comprehensive examination, but (on the contrary) favor it and its associated intent.

The T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE DIVISION OF ENGINEERING DRAWING

FREDERIC G. HIGBEE, EDITOR

Summary of report of the Summer Session Committee.

Examinations and Tests of Achievement

The committee concluded its report with the following recommendations:

"1. That the Drawing Division of the S. P. E. E. be requested to make a careful survey of the present status of Placement and Achievement tests among our teachers of freshmen engineers.

"2. That, through the Drawing Division, an attempt be made to conduct a co-operative testing program between small groups of colleges whose methods and course content are somewhat similar."

Descriptive Geometry Problem

"There is one problem over which I spent some time before solving and would like to know the solution of others for the same type problem; that is, having given three of the four traces of two planes and the angle between the planes, locate the fourth trace. I would suggest the following set up. *HS* 45° and *VS* 30° with the ground line, *VT* 70° with the ground line, crossing *VS* at 100°, and the angle between the planes *S* and *T* of 75°. What would be the method of locating the two possible settings of *HT*? "

Submitted by Professor F. H. Cherry,
University of California.

Questionnaires

Within the last month, I have filled out two questionnaires on subjects of interest to teachers of engineering drawing. Last year I am sure that I answered as many more. I do not mind the labor of answering, but I rebel that a compilation of results—of vital interest to teachers in this field—is seldom forthcoming. The cure, or the remedy, for this waste? I suggest:

Let the Division of Engineering Drawing agree to authorize questionnaires, and the members bind themselves to answer no questionnaires not licensed. To be licensed, a questionnaire (*a*) must not cover a field of inquiry already investigated; (*b*) must be of value and related to the field of engineering drawing; (*c*) must be filed for reference with the secretary when completed.

This is but the germ of an idea. Let us hope it may germinate into a plan which will encourage inquiry and make the results of it available to all. EDITOR.

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". . . In Engineering practice it is no longer sufficient that a structure or a machine satisfy the requirements of technical formulae. This, of course, will always be prerequisite. But the world today demands that Engineering achievement shall catch and express in permanent form the emotional inspiration that lies behind great planning and great doing."

". . . A group of students, filled with the desire to build magnificiently, to create splendidly, filled with the surging desire of youth to go forth and conquer, not dragons or giants or tyrants, but the last challenges of recalcitrant nature, or to discover unknown principles which will increase human happiness, will not be satisfied with a course content which, though perfectly co-ordinated, yet does not give Engineering Education an opportunity to display the art of inspirational development."

". . . It is essential that, somewhere in our set-up of drawing work, some source of continued interest be provided for the teacher which will match the native enthusiasm of the student. It must be obvious that to restrain the efforts of a good drawing teacher to the mere *finger twitching exercises*, while others have the privilege of making the application to the advanced drawing, can only be depressing to him."

PROFESSOR HARRY M. MCCULLY,
Carnegie Institute of Technology.

CO-OPERATIVE ENGINEERING EDUCATION

W. H. TIMBIE, *Editor*

Twenty-five years is a long forward look, but a short backward look. If anybody had asked me twenty-five years ago how long it would take to obtain a highly efficient co-operative scheme, I would have answered that it would take about fifteen years. But now, after twenty-five years of work, I can see a great many things that have not been brought up to the point of satisfactory fulfillment. This may be due to the fact that I am twenty-five years older than I was, and that my point of view has necessarily changed somewhat.

I do not mean, of course, that in its major phases the co-operative system has not worked. It has. A dispassionate appraisal of it would warrant me in saying that it is so much better than the old system that I am convinced of its worthiness. In its major aspects it has worked out according to schedule. It has met four depressions and has weathered them all. It has been found to be workable in all of the phases of Engineering, in Commerce, in the Applied Arts, in Medicine, in Political Science, and in non-professional fields in connection with Liberal Arts courses. In other words, it is a workable scheme mechanically, and it trains most efficiently for definite professional, and in some cases for non-professional service. For example, in the one medical college which has tried it out, for about six years, the examination of students disclosed that professionally they were considerably ahead of students in the usual non-co-operative courses. This has been found to be true also to a very marked degree in Engineering, Commerce and the Applied Arts, so that from the point of view of making a more efficient professional man, I think there can be no question of its success as compared to the usual non-co-operative methods.

When I say that there are several phases in which it may not have worked to the point which I had expected, I do not mean that it has not worked as well as the non-co-operative courses. Even in the fields where I am in doubt as to its having reached the mark I had anticipated, it has surpassed the non-co-operative courses.

It is hard to define the non-professional aspects. Frankly, I had in mind the idea that the leaven of college life and college ideals would permeate professional affairs more through the co-operative system than through the non-co-operative system. My honest conviction is that the co-operative course has served this purpose, but the one disappointment I have is that it has not served to so high a degree as I had anticipated.

Of course, this is a sheer guess on my part, because an appraisal

of values of this sort is not at all possible except through guessing and through observation of a very superficial type. There are no bases for absolute mathematical statistics in such an appraisal, for it is just a matter of opinion.

Obviously, any professional school has two major functions: first, to train professional men to be good and efficient professional men; and second, to implant in them more deeply the idea of a more unselfish and more altruistic service. For example, it ought to be the purpose of the university, in its professional departments, to train better lawyers, better doctors, better engineers, and at the same time give them, to a higher degree, the spirit of service necessary to enable them to enter positions of influence, and to steer the evolution of affairs in a safe direction. They should not only be proficient professionally, but proficient from the point of view of directors of human thought and action, to the end that life will be better for everybody, and the thing we call civilization a less rickety thing.

The appraisal on professional efficiency is easy to make, and shows that the co-operative system does train much more efficiently in this one item of the professional man's activities. The appraisal as to his influence on the development of sound systems in those items which make up the less tangible, more important phases of life, is very difficult to make. As I said before, my guess is that the co-operative system does add to the intangibles as well as to the tangibles, more than the non-co-operative system does, but I am not sure that we have done all we can to bring it up to the point which was in my mind twenty-five years ago.

This seems to me to be the next big task. Men in important professional positions in law, medicine, engineering and commerce are at key points of leadership. It is not enough to be skilled professionally. It is a lot, but not enough. While we have gone a fair distance in developing in co-operative students the vision necessary to leadership, and further, in my opinion, than the non-co-operative system has gone, I am convinced that having solved the question of professional efficiency, our big problem is now to work out methods by which the problem of the intangibles of leadership outside of professional skill can be solved.

This does not mean more courses in History, Economics, Literature, and so on. It means the introduction of something which the colleges have lost generally, but which they had in former days. It is not a matter of size of colleges; it is a matter of spirit.

I think the problem is fairly before us, and to me there seem to be certain definite methods of a non-pedagogical type which perhaps would aid in its solution. It is to these that we must now give our major thought, and they ought to constitute our points of attack in the years ahead of us.

HERMAN SCHNEIDER, *President*,
University of Cincinnati

ENGINEERING SCHOOLS CONFER ON TEACHING MANAGEMENT OF MEN

A conference on preparing engineers and business school students to deal with and manage men and industrial relations, was held on March 29, 1931, at the home of Mr. S. A. Lewisohn in New York. It was called in order to provide opportunity for discussion of methods and interchange of experience among the men engaged in teaching courses in this pioneer field. Representatives from over twenty business and engineering schools where such courses have been instituted or are in contemplation, together with business executives and others especially experienced in this field, attended.

The conference was the immediate consequence of the report of the Committee on Industrial Relations of the S. P. E. E., presented at Montreal last June, which in discussing the question, "Can The Engineering Student Be Taught to Manage Men?," brought out the importance of courses which will cause the student to become more sensitive to the human factors in his experience and give him a method of approach to problems of human relations. The conference was also an outgrowth of two previous conferences at Mr. Lewisohn's house, called at the instance of industrial leaders in order to put before the deans of engineering schools the importance of preparing engineering students to handle the human as well as the technical aspects of their work.

One of the striking characteristics of the recent conference was the advance made since the earlier conferences. Two years ago, the conference at Mr. Lewisohn's house confined itself almost wholly to discussing the desirability, and even the practicability, of such teaching. At the recent conference, there was such complete assent on this point that the conference took it for granted and settled down immediately to discuss objectives, subject matter and methods.

"To prepare students *to learn from experience* to deal with and manage men and industrial relations, not to produce managers ready-made," was concurred in as the underlying objective of all such courses, in a discussion initiated by Elliott Dunlap Smith, Professor of Industrial Engineering at Yale, and Joseph H. Willets, Professor of Industry at the Wharton School, University of Pennsylvania. The particular aims of such teaching should therefore be (1) to give students an orderly background in regard to industrial relations which will enable them to see their problems in perspective and be the basis of a sound philosophy; (2) to make them more aware

of and sensitive to the human factors in their work; and (3) to develop in them habits of objective, penetrating analysis of their problems of human contacts and of industrial relations.

In discussing subject matter, Joseph W. Roe, Professor of Industrial Engineering at New York University, and Ordway Tead, Lecturer in the School of Business at Columbia University, emphasized two types of material: on the one hand material relating to the history, scope, organization, practices and social significance of industrial relations; and on the other hand material relating to individual human contacts and management. Both added that an understanding of human relations would be aided by vigorous study of the psychology of everyday behavior, taught, not as a dry dissected thing, but as principles underlying the action of living men and groups.

This emphasis on reality was carried forward in the discussion of method led by Professor Herman Feldman of the Tuck School at Dartmouth, Professor John R. Bangs of Cornell, Professor John Younger of Ohio State, and Professor E. H. Schell of Mass. Institute of Technology. While they stressed the importance of flexibility in method, and its subordination to the requirements of the particular course and situation, they also indicated the importance of employing methods that as far as possible expose students to problems, cases or experience, and cause them to think for themselves in regard thereto.

The conference, which was presided over by Mr. C. E. Davies, Assistant Secretary of the A. S. M. E., appointed a committee to arrange for a similar conference next year. The members of the conference were the guests at dinner of Mr. Lewisohn, who presided at the dinner and introduced as speakers Mr. Gano Dunn, President of the J. G. White Engineering Corporation, and Mr. F. W. Willard, Assistant Works Manager of the Western Electric Company. Both speakers stressed the importance of right social thinking on the part of engineering graduates.

The outstanding features of the conference were the unqualified acceptance of the desirability and possibility of preparing engineering and business students for the human side of their work, the emphasis upon focussing such teaching upon preparing students to learn from later experience, the double subject matter of human contacts and of industrial relations, and the importance of methods that, as well as retention of information and development of understanding, bring about individual thought and action on the part of the student.

SECTIONS AND BRANCHES

At the Spring Meeting, Ohio Section, held at Antioch College, April 25, the following officers were elected for the year 1931–32:

Chairman: Walter A. Gilmour, Municipal University of Akron.
Vice-Chairmen: T. C. Lloyd, Antioch College, Samuel B. Folk, The Ohio State University.
Secretary: Sada A. Harbarger, The Ohio State University.

Minutes of the Organization Meeting of the Texas Section.—At the invitation of Dean F. C. Bolton, seventy-five teachers of engineering or related subjects met at College Station on the evening of April 3 to form a Texas Section of S. P. E. E.

At the banquet which was complimentary to the visiting delegates, Dr. F. E. Giesecke presided as toast master and introduced President T. O. Walton who welcomed the visitors to A. & M. College. Dean Bolton explained the purposes of the gathering and outlined the advantages to be obtained by the formation of a Texas Section of S. P. E. E., and also the proper method of procedure. Representatives from other institutions were called upon for short talks and all expressed a desire to see such an organization formed.

At the business session which followed the banquet, Dr. F. E. Giesecke was elected temporary chairman of the meeting. It was moved that we proceed to form a permanent organization. Carried. Moved that the chairman appoint a committee of three to draft a constitution. Carried. Professor E. C. H. Bantel, Dean F. C. Bolton, and Dean E. H. Flath were appointed. Their report was unanimously adopted as the constitution of the permanent organization and is included as part of these minutes. The following permanent officers were then elected:

President—Dr. F. E. Giesecke, Texas A. & M. College.
Vice-President—Dean W. J. Hiller, Texas Technological College.
Secretary-Treasurer—Professor J. A. Correll, University of Texas.
Executive Committee:

Dean F. C. Bolton, Texas A. & M. College,
Professor L. B. Ryon, Rice Institute,
Professor E. C. H. Bantel, University of Texas,
Professor C. L. Svensen, Texas Technological College,
Professor F. M. Smith, North Texas Agricultural College, Arlington, Texas

Dean E. M. Flath, Southern Methodist University,
Professor H. C. Doremus, Jno. Tarleton Agri. College,
Dean R. L. Peuriqoy, College of Arts & Industries, Kingsville,
Professor J. W. Kidd, School of Mines, El Paso.

After some discussion the selection of the time and place for the annual meeting was left to the executive committee. The meeting then adjourned.

On Saturday morning, April 4, 1931, the following program was presented:

TECHNICAL MEETING

Chairman—Professor J. J. Richey, Texas A. & M. College

Rainfall Characteristics of South Texas. Professor W. E. White, Rice Institute.

Discussion.

Objectives of Surveying Courses. Professor O. V. Adams, Texas Technological College.

Discussion.

Recess.

The Development of our Freshman Problem's Course. Professor Charles Crawford, Texas A. & M. College.

Discussion.

Open floor discussion of the aims and objectives that may be considered common to nearly all courses in engineering.

Adjournment.

Those attending the organization meeting were as follows:

Name	*Institution*	*Department*
L. E. Grinter	A. & M.	Civil Engineering
Edgar W. Dunn	"	Drawing
C. W. Burchard	"	Chemistry
H. C. Spencer	"	Drawing
C. C. Palmer	"	Electrical
S. J. Boller	Texas Tech.	Drawing
Elmer Hall	" "	Mechanical Engineering
O. V. Adams	" "	Civil Engineering
H. T. Godeke	" "	Mechanical Engineering
O. C. Perryman	" "	Engineering Drawing
O. D. Brandt	" "	Textile Engineering
W. E. Long	A. & M.	Mechanical Eng.
W. E. Street	Texas Tech.	Engineering Drawing
F. E. Giesecke	A. & M.	Engineering Research
R. D. Campbell	S. M. U	Mechanical Eng.
Sophus Thompson	"	Civil Eng.
Bob Slaymaker	"	Mechanical Engineering
R. S. Landon	"	Mechanics
M. K. Thornton, Jr	A. & M.	Chemical Eng.
Joseph W. Ramsay	Texas Uni.	Electrical Eng.

M. C. Hughes	A. & M.	Electrical Eng.
H. F. Huffman	S. M. U.	Electrical Eng.
J. A. Correll	Texas Uni.	Electrical Eng.
B. H. Gafford	" "	Electrical Eng.
E. H. Flath	S. M. U.	Dean of Eng.
Geo. Summey, Jr	A. & M.	English
E. W. Steel	"	Sanitary Engineering
A. E. Finlay	"	Mathematics
H. R. Brayton	"	Chemistry
C. C. Hedges	"	Chemistry
A. V. Brewer	"	Mechanical Engineering
H. Dillingham	"	Electrical Eng.
D. W. Fleming	"	Mechanical Eng.
Robert L. Mills	"	Pet. Production Eng.
C. E. McCarter	Texas Uni.	" " "
W. W. McCarter	A. & M.	Mechanical Eng.
E. W. Markle	"	Electrical Eng.
R. P. Ward	"	" "
A. H. Kerns	"	" "
J. B. Bagley	"	Textile Engineering
C. H. Winkler	"	Vocational Teaching
J. M. Kuehne	Texas University	Physics
B. E. Short	" "	Mechanical Eng.
J. H. Pound	Rice Institute	" "
J. S. Waters	" "	Electrical Eng.
John A. Focht	Texas Uni.	Civil Engineering
J. J. Richey	A. & M.	" "
E. C. H. Bantel	Texas Uni.	" "
J. T. L. McNew	A. & M.	" "
H. C. Doremus	John Tarleton	Engineering
N. F. Rode	A. & M.	Electrical Eng.
Phil. M. Ferguson	Texas Uni.	Structural (Civ. E.)
L. B. Ryon	Rice Institute	Civil Engineering
L. Vernon Uhrig	" "	Civil Engineering
R. R. Crookston	" "	Mechanical Eng.
B. P. Reinsch	S. M. U.	Mathematics
W. E. Hollingsworth	North Texas Ag. Col.	Electrical Eng.
S. A. Lynch	" " " "	Mathematics
W. E. White	Rice Institute	Civil Engineering
T. A. Munson	A. & M.	Civil Engineering
Geo. L. Dickey	N. T. A. C.	Sociology
H. D. McMurtray	"	Physics
F. B. Plummer	Texas University	Petroleum Engineering
R. B. Newcome Jr	" "	" "
F. C. Bolton	Texas A. & M.	Dean of Engineering
J. M. Miller	Rice Institute	Engineering Drawing
T. O. Walton	A. & M.	Adm.
O. W. Silvey	A. & M.	Physics
J. R. Jenness	S. M. U.	Physics
Banks McLaurin	Texas University	Civil Engineering
A. Mitchell	A. & M.	Eng. Drawing
C. E. Rowe	Texas University	Eng. Drawing
M. C. Stone	N. T. A. C.	Head, Dept. Engr.
C. M. Crawford	A. & M.	Mechanical Eng.
Frank Smith	N. T. A. C.	Engineering Dept.

Constitution of the Texas Section of the Society for the Promotion of Engineering Education

Section 1. Name.

The name of this organization shall be the Texas Section of the Society for the Promotion of Engineering Education.

Section 2. Objects.

The objects of the section shall be the promotion of the highest ideals in the conduct of engineering education with respect to administration, curriculum, and teaching work and the maintenance of a high professional standard among its members.

Section 3. Membership.

Membership in the section shall be open to all members of the Society for the Promotion of Engineering Education residing in the State of Texas.

Section 4. Dues.

The annual dues shall be fifty cents.

Section 5. Officers.

The officers shall consist of a president, vice-president, and a secretary-treasurer.

Section 6. Executive Committee.

There shall be an executive committee consisting of the officers and of one member from each of the colleges in the State which maintains a course in engineering. The President of the Section shall be chairman of the Executive Committee.

Section 7. Annual Meeting.

The Executive Committee shall arrange for an annual meeting and present a program for it. These meetings shall be open to all persons interested in engineering education.

Section 8. Election.

The officers and the members of the Executive Committee shall be elected annually at the annual meeting. They shall take office at the close of the annual meeting at which they were elected.

Section 9. Amendments.

This Constitution may be amended by a two-thirds vote of those present at any regular meeting of the section.

AMERICAN ASSOCIATION OF PHYSICS TEACHERS

The first regular meeting of the **American Association of Physics Teachers** was held at the Bureau of Standards in Washington on Thursday, April 30. The meeting was addressed by Dr. Albert W. Hull, Assistant Director of Research at the General Electric Company, on the subject, "Qualifications of a Research Physicist." The discussion was led by President Karl T. Compton of Massachusetts Institute of Technology. The attendance was about 600.

A dinner and business meeting were held in the evening at which there was general discussion of the plans of the organization. The first annual meeting will be held in New Orleans in connection with the meetings of the A. A. A. S., probably on December 31. The programs for this meeting are being arranged by the Executive Committee. Application has been made for affiliation with Section B of the A. A. A. S.

The Association, which was organized at the Cleveland meeting, now numbers 400 members. The campaign for increase of membership is continuing. Applications received prior to June 1 will result in enrollment of the applicant as a charter member. The secretary of the Association is Professor William S. Webb, University of Kentucky, Lexington, Ky.

COLLEGE NOTES

Massachusetts Institute of Technology.—A gift of $170,000 from the Rockefeller Foundation has been announced to be used for research in physics, chemistry, geology and biology, at the Massachusetts Institute of Technology. The fund, which is to be distributed over a period of six years, is intended to supplement the comprehensive plans of Technology for extension of its work in fundamental research, and to demonstrate the importance of investigations in basic sciences.

On May 2nd, in the afternoon and evening, more than 25,000 visitors attended the Institute's ninth annual "Open House." The affair was planned and carried out by the Combined Professional Societies—a student organization. Laboratories and research projects were shown, with students carrying on the regular work. A feature of the occasion was an exhibit in honor of Michael Faraday, showing working models of the apparatus which he used in his electro-magnetic experiments a century ago.

Yale University.—Mr. R. E. Doherty, Consulting Engineer of the General Electric Company, has been appointed Professor of Electrical Engineering in the Sheffield Scientific School of Yale University. Professor Scott will continue as Chairman of the Department during the coming year when he will have reached the retiring age and Professor Doherty will then become the head of the Department.

NEW MEMBERS

FILIPETTI, GEORGE, Professor of Economics, University of Minnesota, Minneapolis, Minn. Frederic Bass, O. M. Leland.

GARCELON, WARREN R., Teacher of Applied Mathematics and Mechanical Drawing, Vallejo Senior High School, Vallejo, Calif. F. L. Bishop, Nell McKenry.

HANNAFORD, EARLE S., Supervisor of Education and Training, American T. & T. Co., Atlanta, Ga. G. C. Anthony, Kendall Weisiger.

HOGAN, MERVIN B., Lecturer in Mechanical Engineering, University of Utah, Box 28, Salt Lake City. R. B. Ketchum, A. L. Taylor.

HOWARD, ALAN, In charge of Educational Work, Advanced Courses in Engineering, General Electric Company, Schenectady, N. Y. Philip L. Alger, M. M. Boring.

KARELITZ, GEORGE B., Associate Professor of Mechanical Engineering, Columbia University, New York City. F. L. Eidmann, W. A. Shoudy.

MANTELL, CHARLES L., Instructor in Chemical Technology, Pratt Institute, Brooklyn N. Y. S. S. Edmands, Allen Rogers.

MCMASTER, ALLEN S., Instructor in Engineering Mathematics, University of Colorado, Boulder, Colo. C. A. Hutchinson, W. K. Nelson.

SLAYMAKER, ROBERT R., Assistant Professor of Mechanical Engineering, Southern Methodist University, Dallas, Texas. R. D. Campbell, E. H. Flath.

TOPPING, ALANSON N., Professor of Electrical Engineering, Purdue University, Lafayette, Ind. C. F. Harding, D. D. Ewing.

WATERS, JAMES S., Instructor in Electrical Engineering, Rice Institute, Houston, Texas. H. K. Humphrey, J. M. Miller.

WILSON, FRANCIS W., President, Wilson Engineering Corp., College House Offices, Harvard Square, Cambridge, Mass. F. L. Bishop, Nell McKenry.

196 new members, 1930–31.

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NECROLOGY

CLAUDE IRWIN PALMER

Claude Irwin Palmer, dean of students and head of the department of mathematics at Armour Institute of Technology, died suddenly April 9, 1931.

Dean Palmer was born May 31, 1871, near Battle Creek, Michigan, and his early boyhood was spent on a farm near Lake View, Montcalm County, Michigan. From the age of thirteen he earned his own living and financed his own education. After graduation from high school he taught in district schools, then took the Normal course at the Ferris Institute at Big Rapids, taught in public schools for nine years, and eventually entered the University of Michigan, where he took the degree of Bachelor of Arts in 1903. For nearly 28 years, until his death, he was a member of the faculty of Armour Institute of Technology in the department of mathematics, holding successively the positions of instructor, assistant professor, associate professor, and eventually professor of mathematics, head of the department, and dean of students.

A profound student of mathematical theory, he was especially interested in the history and the early literature of the science. He was the author of a notably successful series of textbooks titled Practical Mathematics, and of five texts of college grade, in several of which he collaborated with other members of the faculty of the Institute.

Dean Palmer was a member of the American Mathematical Society, the Mathematical Association of America, the American Association for the Advancement of Science, and the Society for the Promotion of Engineering Education; and of the University Club of Chicago, the Armour Faculty Club, the Midway Athletic Club, and the National Arts Club of New York. He was an elder of the First Presbyterian Church of Chicago.

A just and a kindly man, Dean Palmer had great ability as a teacher, and exceptional qualifications as a guide and a friend to students. His memory will long remain in the minds of his colleagues.

A. J. WOOD

A. J. Wood, Head of the Mechanical Engineering Department at Pennsylvania State College, was struck by a motorcycle in front of his home about noon Saturday, April 18, and died in the Centre County Hospital at Bellefonte about five hours later.

Arthur Julius Wood was born September 3, 1874, in Newark, N. J., of deVolson Wood and Frances (Hartson) Wood. His father was a professor of thermodynamics at the University of Michigan and, later, of mechanical engineering at Stevens Institute of Technology, and was well known in his day and profession as an engineer, writer and teacher. Prof. Wood came from New England ancestry.

He was graduated from Stevens Institute with the degree of Mechanical Engineer in 1896 and for the four years immediately thereafter was associate editor of the *Railroad Gazette*. From 1900 to 1902 he was an instructor in Worcester Polytechnic Institute, and went from there to Delaware College as Professor. He came to Penn State in 1904 with his wife Helen M. Kerr, whom he had married that same year. From that time until 1908 he was assistant professor of experimental engineering, being promoted to associate professor and holding that rank to 1910, when he was made associate professor of railway mechanical engineering. In 1918 he was made Professor of Railway Mechanical Engineering and in 1922 was made head of the department of mechanical engineering with a full professorship. For three years, from 1919 to 1922, he was in charge of the Thermal Plant of the Engineering Experiment Station.

His contributions to the literature of engineering fall in the categories of heat transmission, railway mechanical engineering, and refrigeration. He published one textbook, on "Locomotive Operation and Train Control," and was the author of about fifty monographs, bulletins and articles on the above-mentioned subjects.

He was president of the American Society of Refrigerating Engineers during their 25th anniversary year, 1929; had served the American Society of Mechanical Engineers on their committee on heat-transfer, and also as chairman of the local (Central Pennsylvania) section, in 1922. He was also a member of the American Railway Association (mechanical Division), of the Society for the

Promotion of Engineering Education, a fellow of the American Association for the Advancement of Science, honorary member of Sigma Tau fraternity, member of the honorary engineering fraternity, Pi Tau Sigma.

His contribution to the teaching of mechanical engineering consists in the formulation of the course of study, in the building up of a staff of instructors devoted to him and working smoothly together, and in turning out a body of alumni who have been quite uniformly successful.

BOOK REVIEW

Principles of Engineering Thermodynamics. By Paul J. Kiefer, Professor of Mechanical Engineering, U. S. Naval Post Graduate School, and Milton C. Stuart, Professor of Experimental Mechanical Engineering, Lehigh University. John Wiley and and Sons, Inc., New York. 545 pages. Price $4.50.

Whatever relevancy a new book on engineering thermodynamics may have to immediate problems and developments in engineering practice, its success as a textbook will depend principally upon the clarity of its exposition of the first and second laws of thermodynamics, and the precision with which it traces understandingly the implications of these laws and their practical consequences. In this respect, "Principles of Engineering Thermodynamics" by Kiefer and Stuart is a fortunate contribution. It is pertinent to practice. But of more importance, it clarifies fundamental theory.

One need not be in immediate accord with the complete terminology employed by the authors to recognize that in their insistence upon exactness and consistency lies one principal reason for their success in simplifying the explanation of practical processes, and no small part of the educational value of the book. A clear distinction is drawn between energy stored in a system and energy in a state of transition. Heat and work are forms of the latter, potential and kinetic energy are forms of the former. Entropy is described as an index of the unavailability of energy. The term heat content is discarded and the term enthalpy is substituted.

Parts I and II deal with energy and the availability of energy. Subsequent chapters deal with the properties of liquids and vapors; gases and gas-vapor mixtures, including humidity and hygrometry; nozzles, orifices, diffusers, ejectors, etc.; steam power plant cycles, such as the Rankine cycle, the regenerative cycle, the reheat-regenerative cycle, and binary vapor cycles; the reciprocating engine; the steam turbine; combustion; internal combustion engines; compressors and blowers; refrigeration, and general thermodynamic equations.

The book will reward the serious student capable of sustained concentration and close reading.

L. H.

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ADDITIONAL NEW MEMBERS

BABBITT, ARTHUR B., General Manager, Kent Machine Works, Earl Ave., Kent, Ohio. W. W. Edwards, C. W. Banks, F. E. Dobbs.

BENNER, J. ALFRED, Assistant Professor of Mathematics, Lafayette College, Easton, Pa. D. A. Hatch, E. H. Rockwell.

BENNETT, CLAUDIUS E., Acting Associate Professor of Electrical Engineering, University of North Carolina, Chapel Hill, N. C. E. W. Winkler, John E. Lear.

BLOSSOM, FRANCIS, Civil Engineer, Sanderson & Porter, 52 William St., New York City. Gano Dunn, Charles F. Coun, F. L. Bishop.

BOURDELAIS, GEORGE A., Instructor in Engineering, Swarthmore College, Swarthmore, Pa. Chas. G. Thatcher, Scott B. Lilly.

BOWMAN, JAMES H., Instructor in Electrical Engineering, Purdue University, Lafayette, Ind. D. D. Ewing, C. F. Harding.

BRADLEY, JAMES A., Associate Professor of Chemical Engineering, Dean, Newark College of Engineering, Newark, N. J. V. T. Stewart, F. L. Bishop.

BROWN, HAROLD W., Consulting Engineer, 1437 Rugby Road, Schenectady, N. Y. Ernest E. Johnson, Carrol G. Brown.

CHEATHAM, JAMES C., Instructor in Mechanical Engineering, A. & M. College of Texas, College Station, Texas. C. W. Crawford, V. M. Faires.

HASKINS, GEORGE W., Associate Professor of Aeronautical Engineering, Purdue University, Lafayette, Ind. H. L. Solberg, J. D. Hoffman.

JENNESS, LESLIE G., Instructor in Chemical Technology, Pratt Institute, Brooklyn, N. Y. S. S. Edmands, Allen Rogers.

MARIN, JOSEPH, Instructor in Civil Engineering, Rutgers University, New Brunswick, N. J. P. H. Daggett, A. R. Johnson.

PENRIQOY, ROBERT L., Director of Engineering, Professor of Civil Engineering. Texas College of Arts and Industries, Kingsville, Texas. F. C. Bolton, F. E. Giesecke.

RAMSAY, JOSEPH W., Associate Professor of Electrical Engineering, University of Texas, Austin, Texas. J. A. Correll, E. C. H. Bantel.

REINSCH, BERNHARD P., Professor and Head, Department of Mathematics, Southern Methodist University, Dallas, Texas. E. H. Flath, R. D. Campbell.

RICE, ANDREW C., Instructor in Chemical Technology, Pratt Institute, Brooklyn, N. Y. S. S. Edmands, Allen Rogers.

SHORT, BYRON E., Adjunct Professor of Mechanical Engineering, University of Texas, Austin, Texas. A. Vallance, C. Eckhardt.

STONE, RALPH B., Associate Professor of Mathematics, Registrar, Purdue University, Lafayette, Ind. C. F. Harding, R. B. Wiley.

TROFIMOV, LEV A., Development Engineer in charge of Research and Development Department, Electric Controller and Manufacturing Co., Cleveland, Ohio. E. S. Foster, F. L. Bishop.

WHELAN, DANIEL E., JR., Professor of Civil Engineering, Loyola University at Los Angeles, Calif. D. M. Wilson, G. H. Dunstan.

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